ENERGY POLICY IN THE GREENHOUSE
VOLUME II, PART 2

Cutting Carbon Emissions While Making Money

Climate Saving Energy Strategies for the European Union

EXECUTIVE SUMMARY

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CUTTING CARBON EMISSIONS WHILE SAVING MONEY:
Climate Saving Energy Strategies for the European Union

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About IPSEP

The International Project for Sustainable Energy Paths (IPSEP) is a private research organization based in California, with associates in the U.S. and Europe. IPSEP's research focuses on energy and development policies that integrate mitigation of global warming pollution with energy and economic productivity improvements and with greater equity between the rich and poor nations of the world.

Research summaries and reports are available at http://www.ipsep.org, or by contacting IPSEP, 7627 Leviston Ave, El Cerrito, CA 94530, Tel. (510) 525 7530, Fax (510) 525 4446.

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The views expressed in this report are not necessarily those of the funders or other organizations mentioned.

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Short Summary

The challenge of carbon mitigation is not one of managing and sharing economic pain, but one of mobilizing and sharing economic gains. This is the principal conclusion of the following report, which presents the results of a multi-year research project on low-carbon energy futures for the European Union (EU-15). The study, which was carried out by the International Project for Sustainable Energy Paths (IPSEP), confirms that EU carbon emissions can be reduced significantly below 1990 levels. Going beyond previous work, it also provides a detailed cost assessment of such carbon mitigation.

Overall Results

IPSEP's economic assessment points to fundamental misperceptions of the costs of carbon mitigation, both in Europe and elsewhere. Conventional wisdom has it that abatement of greenhouse gas emissions would unavoidably involve across-the-board economic losses and pain; that such costs may be justified as the price of buying insurance against the threat of climate change; and that governments need to negotiate a difficult course between the environmental advantage of early action and the perceived economic advantage of later action.

The present analysis turns conventional wisdom upside down. It shows that if climate policies emphasize productivity-enhancing technologies, carbon-cutting investment shifts will result in substantial net economic gains — even before the benefits of avoided climate risks and damages are counted. Though mitigation will involve significant administrative and political challenges, meeting these challenges will bring ample rewards, especially for regions that take early concerted action.

The conventional notion of unavoidable losses is traced to the use of outdated economic models, often compounded by grossly incomplete presentations of technology menus, policy options, and technological change. Such models are ill-suited for simulating innovative productivity-enhancing energy policy options. In the present study, these shortcomings are overcome by relying on modern information economics, transaction cost economics, and institutional economics in modeling the economic effects of climate policies and technological change.

The finding that climate change mitigation can be profitable for the European Union has profound implications. First, it establishes a new focus for energy policy within the EU that goes beyond energy market liberalization. Second, it provides a new definition of the European Union's enlightened self-interest in the context of international negotiations: The EU could gain both domestic and international competitiveness advantages through concerted regional action to meet and exceed Kyoto commitments. And provisions in the Kyoto protocol calling for emphasis on domestic emission reductions in Annex I countries (rather than unmitigated "elsewhere" flexibility) are supportive of economically efficient greenhouse gas mitigation, both in Europe and globally.

What Emission Reductions Are Feasible

In the present study, baseline growth of economic output, energy consumption, and emissions is based on scenarios elaborated by the European Commission. The potential reach of low-carbon resource options is evaluated assuming the same stocks of vehicles, buildings, appliances, and industrial plant, and the same usage levels. Careful attention is paid to the retrofit and replacement cycles for energy-using capital stocks. This technical-logistic analysis yields the following results (Figures 1 and 2):

- The EU has sufficient low-carbon energy resources and technology options to cut year 2010 carbon emissions to 75 percent of 1990 levels and 2020 carbon emissions to 50 percent of 1990 levels.

In formulating carbon reduction scenarios, policy effectiveness is also taken into account (Figure 3):

- Assuming plausibly imperfect policies starting in 2000 that will mobilize no more than 50-65 percent of Europe's efficiency and other low carbon resource potentials, the European Union could cut its emissions by 8 percent below 1990 levels in 2010 (i.e., meet its Kyoto target through domestic measures alone).
- Assuming the same policy effectiveness, carbon emissions in 2020 could be cut by 17 percent below 1990 levels (i.e., twice the Kyoto commitment for 2010), on account of more complete turnover of buildings, vehicles, plant and other energy-using capital stocks.

These successively larger emission reductions are feasible while more than doubling gross domestic

Figure 1:
EU-15 Carbon Emissions in Year 2010
for Alternative Scenarios

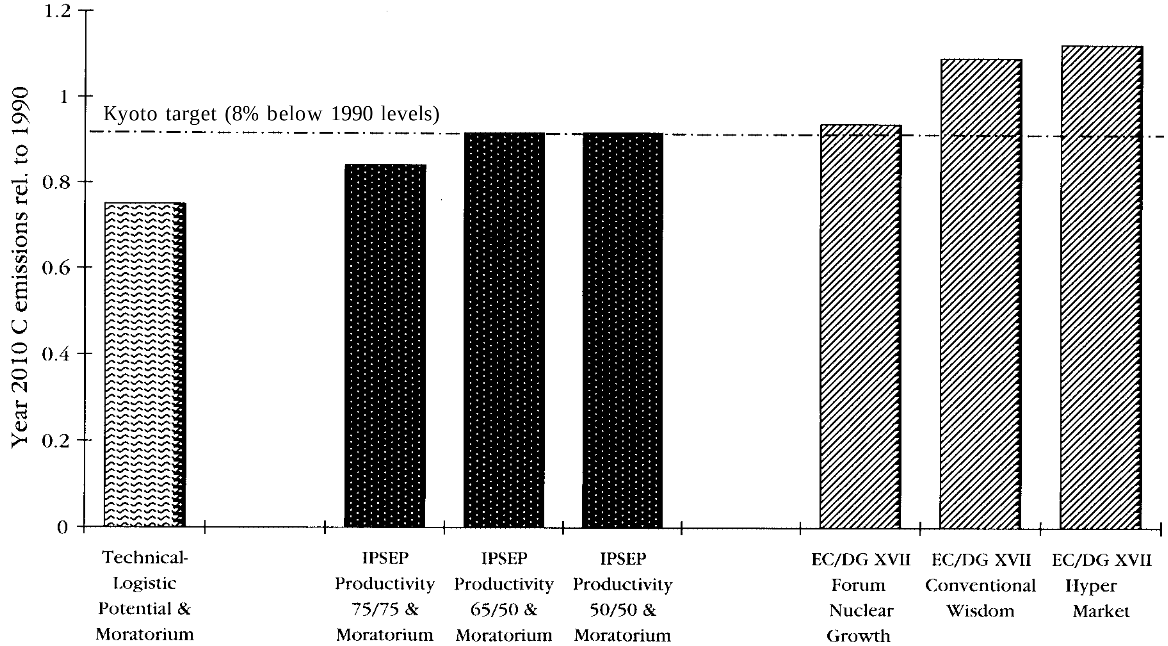
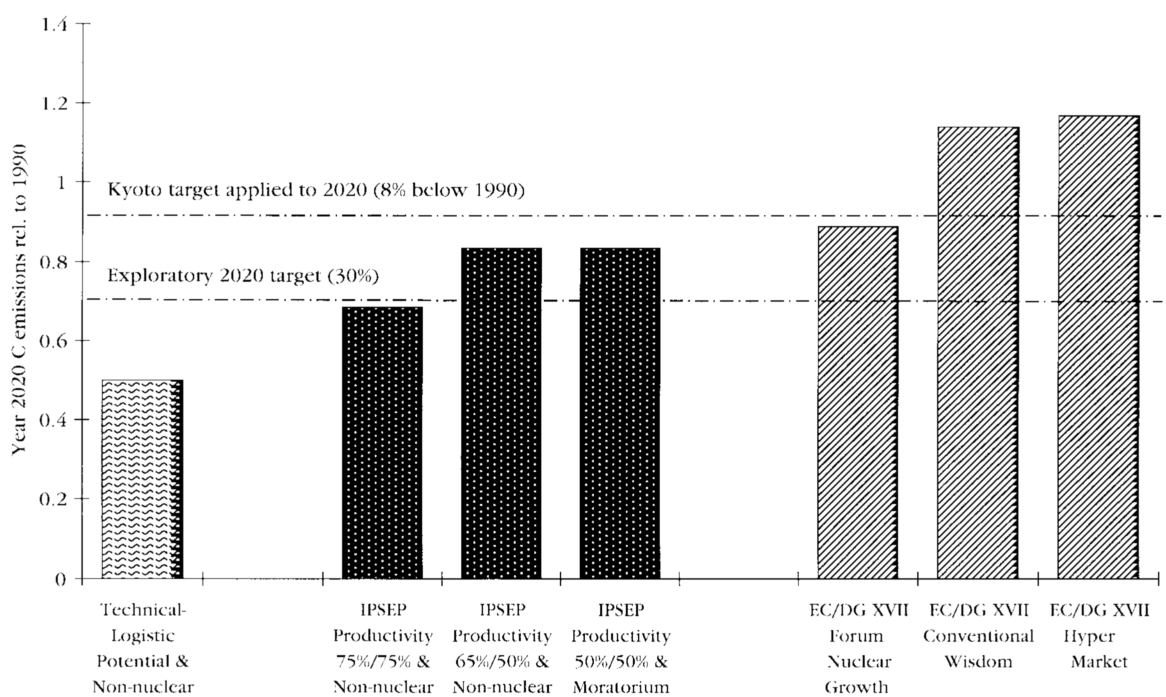


Figure 2:
EU-15 Carbon Emissions in Year 2020 for Alternative Scenarios



product, and while lowering natural gas requirements in the EU significantly below current trend projections.

Moreover, the above reduction percentages are achieved with the assumption of an accelerated phase-out of nuclear power by 2020. They show that the EU has technological choice in meeting global environmental goals, rather than having to trade off nuclear and climate risks.

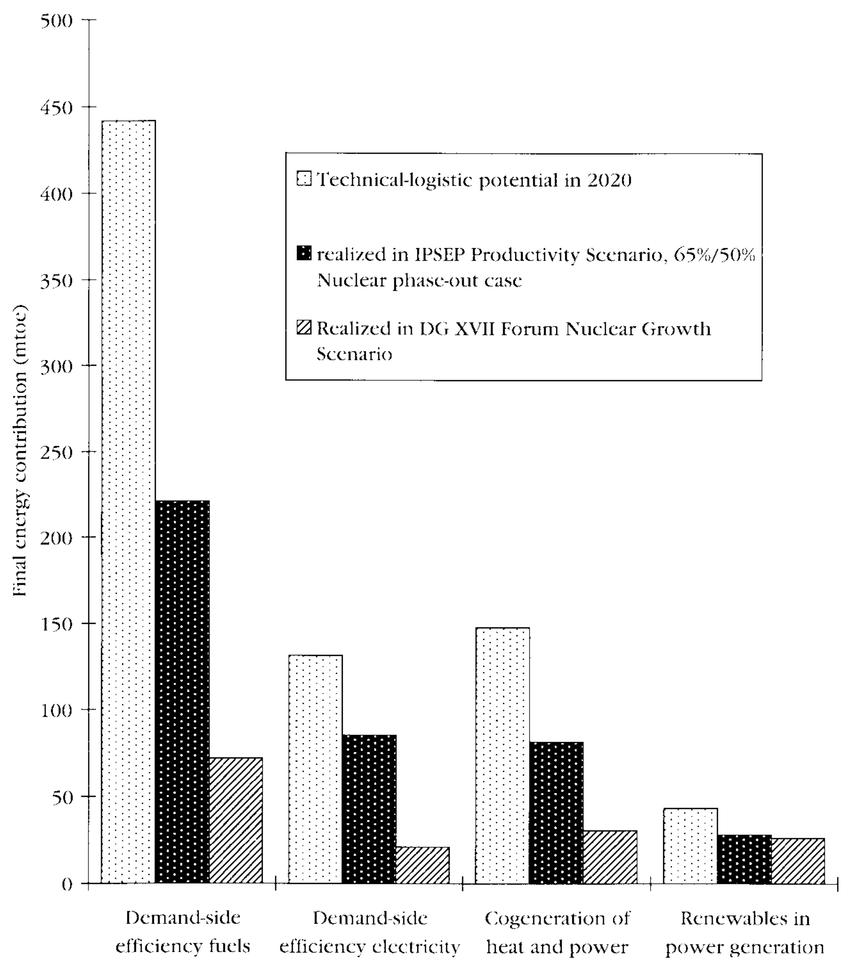
How Low Carbon Strategies Save Money

The present study finds that the above cuts in Europe's carbon emissions are feasible while saving money, enhancing employment, and strengthening the technological competitiveness of the EU. This encouraging finding is based on five separate sources of monetary savings, which are summarized below.

1. Productivity Gains from Energy Efficiency Investments

The key for making carbon abatement into a profit center for the European Union is investing in increased energy productivity, which also enhances total factor productivity of capital, labor and energy combined. The main technologies capable of producing such gains are cogeneration of heat and power on the supply side, and more efficient vehicles, buildings, appliances, and other equipment on the demand-side. Typically, the energy efficiency of present EU capital stocks can be improved by a factor of two to four.

Figure 3:
Realization of Efficiency, Cogeneration, and Renewables Potentials in Alternative Scenarios for the EU-15, Year 2020



Most investments in these efficiency options are highly profitable from a private life cycle cost perspective, and more so when compared to the average opportunity cost of capital in the economy at large. However, while rates of return are high, the absolute magnitudes of monetary savings from individual measures or projects are often small compared to the overall budgets of households or the total production costs of firms. As a result, energy productivity investments are easily blocked by high information and transaction costs. Other pervasive market barriers, such as split incentives between renters, builders, and owners, and organizational processes within firms, compound these barriers.

Innovative but proven market-enhancing policies, such as demand-side management programs, energy efficiency standards, and government-sponsored voluntary agreements, can overcome these barriers at small administrative expense, yielding major net economic savings:

- A partial, 50-65 percent implementation of energy productivity potentials would save European consumers and firms about 40 billion ECU per year in 2020 — before considering feedback effects on technology costs, fuel prices, and the electricity mix. This saving represents a 7 percent reduction in total EU expenditures for energy services in that year.

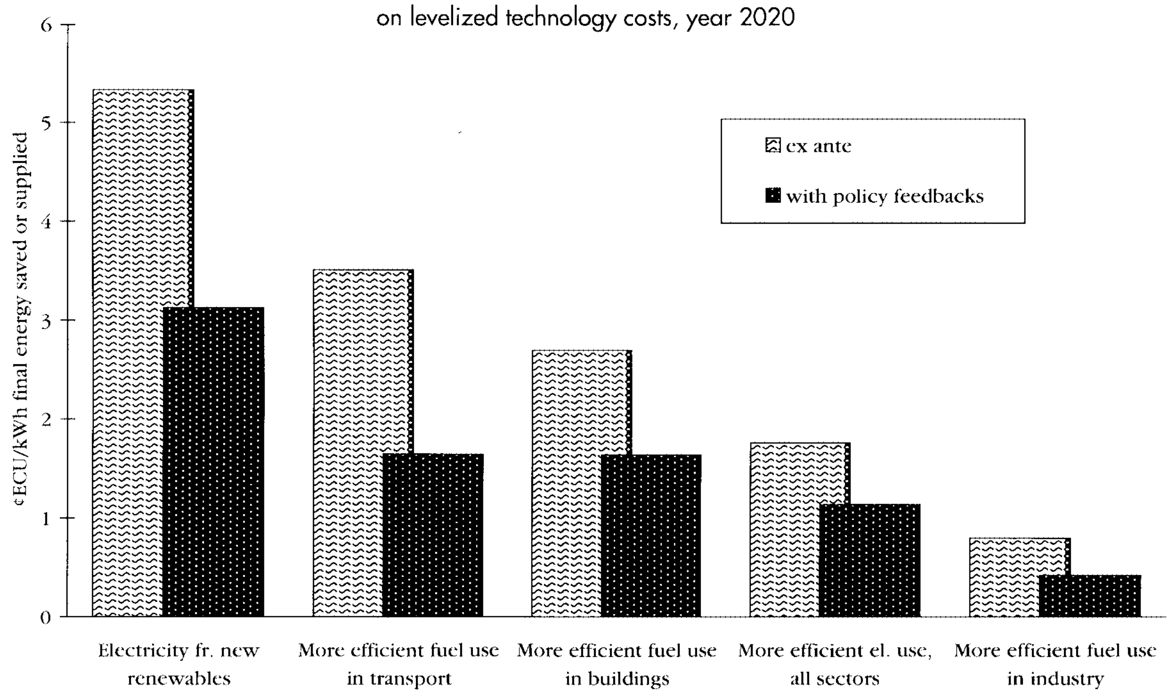
Conventional modeling analyses fail to capture these productivity savings. By using fixed historical coefficients in deriving future energy demand for both their policy and reference cases, they project existing market barriers into the future.

2. Reductions in Technology Costs

One foreseeable feedback effect of strong climate policies identified in the IPSEP study is a steep drop in the investment cost of energy efficiency and renewable energy technologies (Figure 4). Several factors are involved: their suitability for mass manufacturing, high rates of technological learning by doing, economies of scale as market share rises, and downward price pressures once technologies move from niche markets to mass markets.

Though some cost reductions can also be expected for conventional, fossil- and nuclear-based energy supply technologies, remaining potentials for

Figure 4:
Feedback effects of climate policies
on levelized technology costs, year 2020



increasing their production volumes are far more limited. Also, the learning rates per doubling of cumulative production experience are smaller for most of these technologies, and scale effects for big field-erected central stations are already exhausted.

These asymmetries in technological learning and cost reduction potentials not only reduce the cost penalties of renewables on the supply side; they will also increase the cost advantages of energy efficiency technologies on the demand side. This will make EU carbon reductions even more profitable. In the IPSEP study,

- The feedback effects of a well-designed, productivity oriented climate strategy on the costs of demand-side efficiency and renewable energy technologies are estimated to generate additional EU-wide savings of about 50 billion ECU per year in 2020.

Conventional modeling analyses completely overlook these feedback effects on the demand side, and most also do so on the supply side.

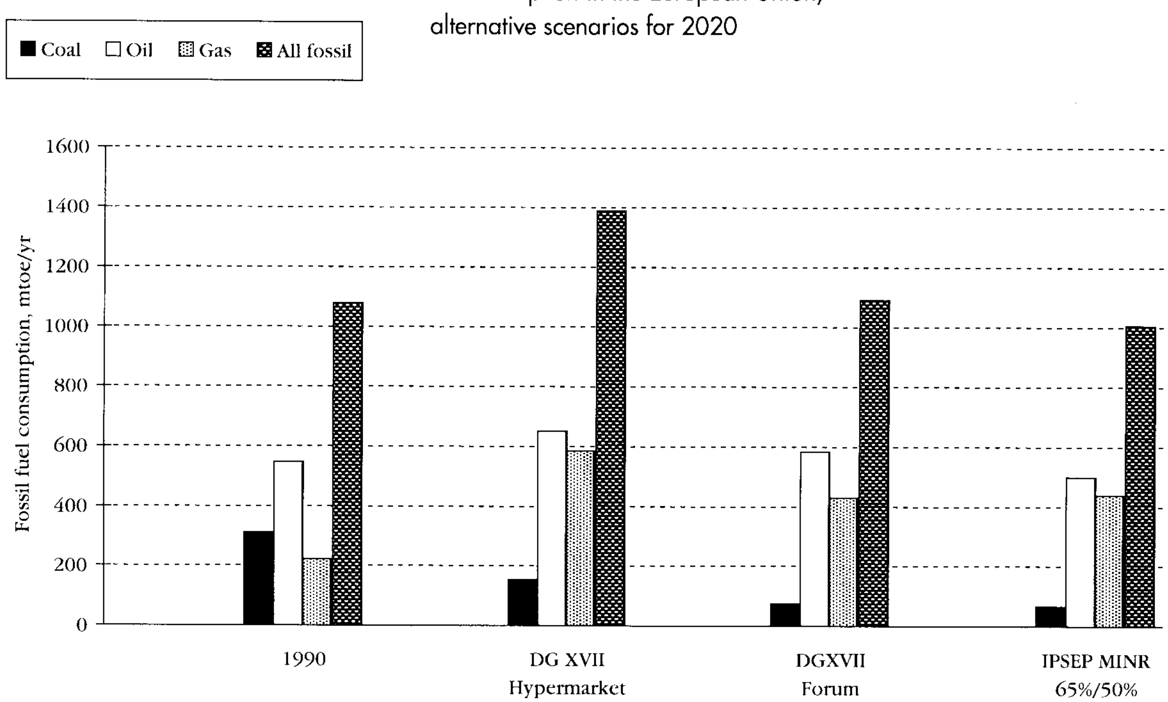
3. Reduced Import Prices for Fossil Fuels

Strong action to protect the world's climate will reduce the pre-tax or import prices of fossil fuels relative to baseline projections. The magnitude of this further benefit of low carbon energy strategies depends on both global and regional changes in fossil energy requirements (Figure 5).

To arrive at a conservative estimate, the present study assumes that the EU will implement its Kyoto commitments for 2010, and will double these cuts by 2020, but that this action would not be matched by other Annex I countries. Nevertheless, wider recognition of the profitability of an investment-led productivity strategy, together with growing economic globalization and technological competition, would lead to at least some shifts of investments and reductions in carbon intensity in other world regions, such as the U.S. and the major developing countries.

Following calculations by the Energy Directorate of the European Commission, these spill-over effects would cut the projected 1990-2020 rise in world fossil fuel consumption by 25 percent, with a sensitive downward price response, due to diminished monopoly pricing power in world oil markets. Meanwhile, domestic action in the EU would keep new gas pipeline capacity below cost-raising thresholds. The resulting fuel price savings for the EU are estimated at about 80 billion ECU/yr in 2020.

Figure 5:
Fossil fuel consumption in the European Union, alternative scenarios for 2020



4. A Cheaper Electricity Supply Mix

Higher energy efficiency in final electricity use results in a lower-cost mix of generating sources. With lower demand, cheap hydro resources and other low-cost plants with limited resource potentials contribute a greater share of total generating requirements. This effect is estimated to add of the order of 10 billion ECU to the above fuel price savings.

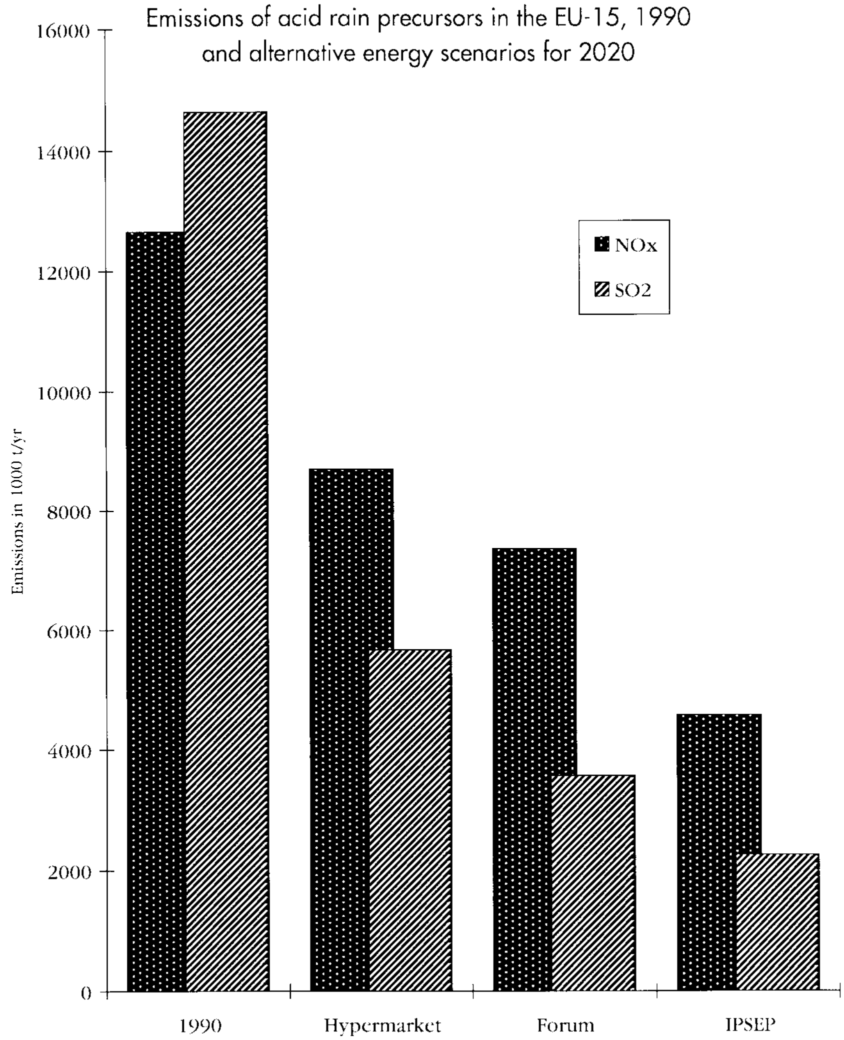
5. Lower Externality Costs

In the baseline projections of the European Commission, emissions of nitrogen oxides (NOx), sulfur dioxide (SO2), and other pollutants and impacts are already lower in 2020 than in 1990. However, large residual pollution effects remain (Figure 6). Carbon reduction strategies have the side effect of reducing these externality costs significantly further:

- A doubling of EU Kyoto targets for 2010 (to 17 percent below 1990 levels in 2020) would reduce EU sulfur dioxide emissions by 60 percent below baseline projections, and nitrogen oxides by almost 50 percent.
- The economic side benefits of these and other reductions in classical pollution impacts are about 10-50 billion ECU per year in 2020.

Monetized estimates of avoided damages from climate change are so highly uncertain that they are not included in this study. However, even partial estimates could easily multiply the economic benefit from reduced externalities.

Figure 6:
Emissions of acid rain precursors in the EU-15, 1990 and alternative energy scenarios for 2020



6. Adding It All Up

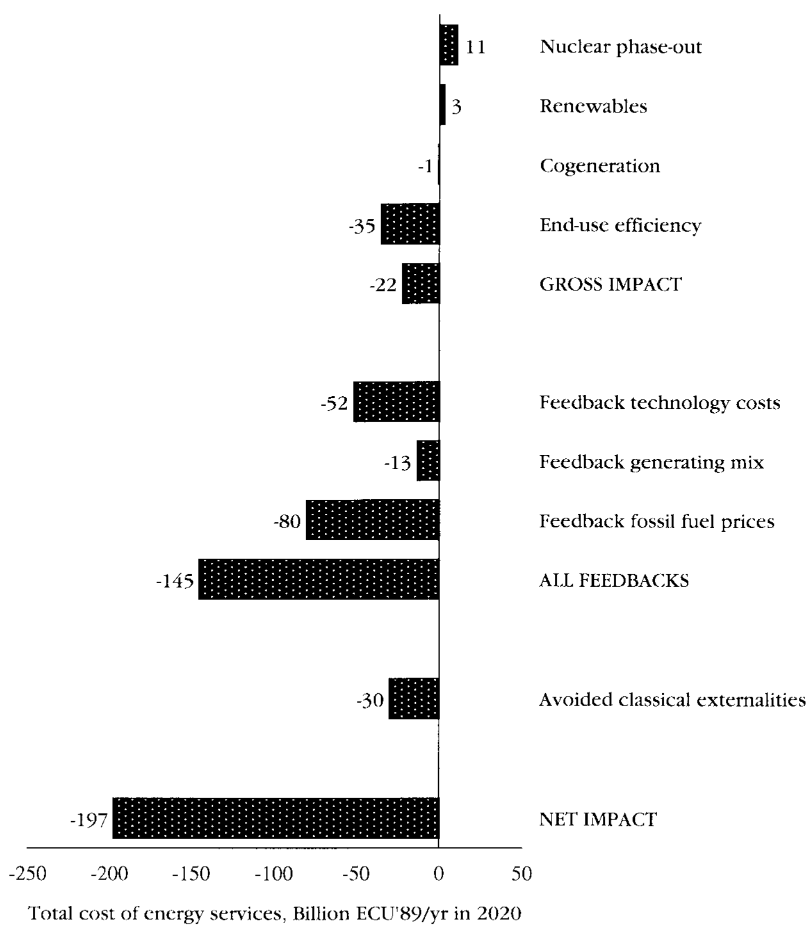
In summary, if the EU doubles its current Kyoto commitment for 2020 and reduces carbon emissions through a strategy of investment-led productivity growth,

- Year 2020 costs of energy services in the EU can be reduced by about 30 percent — before considering the additional benefit of avoided environmental externalities.
- When counting avoided classical externality costs, the total direct benefit for the EU rises to 190-240 billion ECU.

Put another way, a well-designed but realistically imperfect climate protection strategy can free about 2 percent of projected year 2020 gross domestic product for other purposes (Figure 7). The benefit in terms of gdp growth would be even larger than this direct cost savings, due to ripple effects. These multiplier effects were not quantified in this study.

The above savings represent point-value estimates that are surrounded by considerable uncertainty ranges. Still, even if benefits were only half as large, they would be an order of magnitude higher than the estimated direct costs of shifting to an environmentally safer energy supply mix — be that an accelerated phase-out of existing reactors, or a program of buying down the price of new renewable technologies through accelerated market expansion. The same goes for possible additional mitigation costs related to feedback effects from higher than baseline growth.

Figure 7:
Economic impact of CO2 abatement,
IPSEP Productivity MINR 65%/50% scenario
compared to Hypermarket scenario, Year 2020



Domestic Policy Aspects

Current energy policy in the EU is dominated by the notion that energy market liberalization will be sufficient to correct most market problems and ensure least-cost outcomes. While such reforms may improve energy supply markets, they do nothing to overcome market barriers on the demand-side.

What is needed there are targeted programs that eliminate the high transaction costs now blocking energy productivity investments on the demand side. Suitable and proven instruments are voluntary agreements, utility incentive programs, feebates, mandatory minimum efficiency standards, and a range of information, labeling, training and extension services that will build and strengthen the institutional foundations for a functional energy service industry.

To maximize carbon reductions, these demand side efforts will have to be complemented by utility regulatory reforms, such as fair buy-back rates for on-site electricity production, and market creation programs on the supply side, such as portfolio standards for cogeneration and renewable power.

Such market enhancement and transformation policies can be given added effectiveness through energy subsidy reforms, and through a reorientation of R&D programs. To finance these policies and requisite investment incentives, a moderate energy or carbon tax would be sufficient. An EU-wide emissions trading regime could supplement these policies.

It is this multi-faceted policy approach that will make carbon mitigation into a profit center for society. Unfortunately, based on the current state of implementation of policies in the EU, only a small fraction of feasible carbon reductions and economic benefits will be realized. This policy vacuum is found to cost EU consumers and firms dearly:

- Under current policy trends, the total costs of energy services in the EU would remain a third above least-cost levels, even after accounting for some price reductions from energy market liberalization.

International Policy Aspects

Large and widely unrecognized opportunity costs would also be imposed on EU consumers and firms if European countries were to mainly rely on the Kyoto flexibility mechanisms for meeting their carbon targets. The IPSEP study estimates that "elsewhere" flexibility could be economically advantageous for about 10 percent of EU commitments, with the remainder being profitably realized through productivity measures within the European Union.

Major or exclusive reliance on the Kyoto flexibility mechanisms would have the effect of protecting a limited amount of sunk fossil investments in the energy sector, at the expense of energy productivity investments that benefit the economy across the board.

Principal reliance on "elsewhere" flexibility could also slow technological innovation. By extending markets for already commercially established technologies that offer only suboptimal carbon reductions, it could impede money-saving demand-side options in developing countries and Annex I countries alike, and it could delay the realization of learning curve benefits in advancing low cost renewable energy technologies.

Conclusion

The present study suggests that rising global warming pollution, in the EU and elsewhere, is not economic fate but a matter of money-wasting policy choices. The study shows that large carbon reductions are feasible in the European Union, and that these reductions could be implemented while strengthening economic growth, employment, and technological competitiveness. The main challenge of carbon mitigation is not one of managing economic pain or burden sharing, but one of mobilizing economic gains, and benefit sharing. The present analysis clarifies the potential economic rewards of a productivity-oriented climate protection strategy.

I. Introduction

Climate Change Perceptions in the EU

Fifteen percent below 1990 levels — this was the proposal of the European Union for cutting global warming pollution in industrialized countries in the Kyoto climate change negotiations. The EU target was far larger than those proposed by other industrialized countries, and far more than eventually agreed upon. This leadership on the part of the European Commission was possible because of a broad perception in Europe that:

- the science on global warming clearly supports preventative action to cut global warming pollution;
- ample technological options exist for reducing emissions; and
- the benefits of averting the threat of catastrophic climate change easily justify what limited costs might be entailed by mitigation action.

Broad support for these basic propositions is not only found among the general public, but also among many representatives of industry. However, there is an ongoing debate as to the specific strategies and policy instruments that ought to be pursued. Considerable disagreements and confusion still exist over which technology mix would be most preferable and least costly, what the role of nuclear power should be, and whether an aggressive approach would be more expensive or, on the contrary, would offer significant economic, employment, and competitiveness benefits.

At the same time, key positions taken by the European Union in the UN climate change negotiating process have been criticized by the U.S. as economically unaffordable and therefore unrealistic. The present study seeks to clarify these claims.

Conventional Energy Futures

The main reference point for the official EU discussion on energy policy is found in the "European Energy to the Year 2020" scenario exercises published by the Directorate General for Energy (DG XVII) of the European Commission (EC 1996). This work offers the clearest illustration of the conventional, supply-oriented, more centralized energy futures that continue to dominate energy policies in Europe today. As such, the Energy Directorate's scenarios provide an instructive contrast to the more decentralized, demand-oriented strategies that mark the doorway to a sustainable energy future.

The Kyoto target for the EU is about 2900 Mt CO_2 in 2010, or a reduction to 8 percent below 1990 levels.[1] Table 1 summarizes the carbon emission results for the three most important scenarios of the Energy Directorate. In one of these, the so-called Forum scenario (see below), an attempt is made to address climate protection concerns within a predominantly supply-oriented framework. Along with these official elaborations, we also show some of the results obtained in another scenario study by the International Project for Sustainable Energy Paths (IPSEP 1993/1999), which are discussed further below.

The key point borne out by the table is that the climatically unconstrained "business-as-usual" scenarios of the Energy Directorate (i.e., Conventional Wisdom and Hypermarket) overshoot the Kyoto target by about 600 Mt CO_2 in 2010, and by an even bigger amount — 700 to 800 Mt CO_2 — in 2020.[2]

An international carbon target for 2020 has not yet been agreed upon, but it should be consider-ably lower than that for 2010. Given the additional decade for implementing reduction measures, and given that the pre-Kyoto proposal of the EU was 15 percent, a 30 percent reduction below 1990 levels would seem reasonable for 2020. In that case, emissions in the EU-15 would have to drop to about 2200 Mt CO_2.

Table 1 shows that relative to this more stringent target for 2020, all three of the Energy Directorate's scenarios are far amiss. The first two cases, Conventional Wisdom and Hypermarket, produce huge excess emissions of 1400-1500 Mt CO_2 climatic concerns, also misses this target by 600 Mt CO_2.

1. This is a combined target for three greenhouse gases that could also be met by a less than eight percent cut in CO_2 emissions and larger cuts in the other gases. For the purposes of this discussion, we assume an 8 percent target explicitly for CO_2.

2. In this context it is worth noting that the EU Ad-hoc Group on Climate Change (Phylipsen et al. 1997) and staff of the European Commission themselves (EC 1997) have each identified a series of measures that could cut CO_2 emissions by 355-830 Mt in 2010, or about 17% below 1990 levels.

Table 1:
Development of EU-15 carbon emissions under alternative scenarios, 1990-2020

	Year 2010 Emission scenarios EU-15 MtCO2	Difference in carbon emissions relative to Kyoto target MtCO2	relative to 1990 (3166 MtCO2) %	**Year 2020** Emission scenarios EU-15 MtCO2	Difference in carbon emissions relative to a 30% target MtCO2	relative to 1990 (3166 MtCO2) %
Target (2010 Kyoto, 2020 exploratory)	2913		*-8%*	2216		*-30%*
Energy Directorate scenarios						
Conventional Wisdom	3457	544	*9%*	3608	1392	*14%*
Hypermarket	3558	645	*12%*	3699	1483	*17%*
Forum (renewables & nuclear build-up)	2972	59	*-6%*	2817	601	*-11%*
IPSEP Productivity scenarios						
50%/50% el./fuel efficiency & nuclear moratorium	2905	-8	*-8%*	2643	427	*-17%*
65%/50% el./fuel efficiency & nuclear phase-out	2902	-10	*-8%*	2639	423	*-17%*
75%/75% el./fuel efficiency & nuclear phase-out	2668	-245	*-16%*	2169	-47	*-31%*
Technical potential						
IPSEP MINR100% (incl. nuclear phase-out by 2020)	2375	-538	*-25%*	1583	-633	*-50%*

(1) For IPSEP scenarios, 50%/50% stands for 50 percent mobilization of technical potentials of electrical and non-electrical end-use efficiency.

(2) Nuclear moratorium stands for continuing the current de facto moratorium past 2020. Existing reactors have an economic life of 35 years.

(3) Nuclear phase-out includes moratorium on new construction, plus accelerated retirement of reactors that would otherwise still be in service in 2020.

(4) For IPSEP scenarios, mobilization of renewables is same as for electrical efficiency potentials, subject to power system integration constraints.

The IPSEP Study

Quite a different picture emerges from the IPSEP study (IPSEP 1993/1999).[3] Unlike the work of the Energy Directorate, this analysis includes a detailed, multi-volume study of the technological potentials for improving end-use efficiency in the EU. It also includes an in-depth assessment of the EU's cogeneration and renewable power potentials. These resource assessments are then analyzed jointly to clarify whether sufficient domestic low carbon resources are available to reach the above stepping stones in a transition to a sustainable energy system.

This clear exposition of energy efficiency and other potentials makes it possible to separate the question of resource sufficiency, which is largely a technical-logistic issue, from the question of policy implementation, which is largely an issue of political will and choice. Such transparency is routinely absent from official discussions of energy futures. The scenario work of the Energy Directorate is no exception in this regard.

In the IPSEP scenarios, real-world implementation problems and the issues of political economy surrounding alternative energy futures are represented in the form of an implementation fraction. The implementation fraction indicates what percentage of the technical-logistic resource potentials for energy productivity, cogeneration, and renewables is being mobilized in each scenario. This implementation fraction is varied in several steps, from 25 percent to 100 percent of technical-logistic resource potentials. Energy requirements, carbon emissions and costs are then calculated for each case.

Using this framework, the IPSEP study investigates two major groups of scenarios. In the Least Cost (LC) scenarios, resources are integrated on the basis of least economic cost. Low-carbon options enter the mix *up to* the implementation fraction, but only insofar as they are cost-effective. These scenarios provide insights into market failures in the competition between the various energy options: How much money literally "goes up in smoke" in European households and firms, on account of energy-wasting buildings, vehicles, and equipment? What are the lost opportunities inadvertently created by laissez-faire regulatory reforms when energy supply and energy efficiency markets are inefficient to start with?

The second family of scenarios addresses several important societal risks that are generally ignored in purely economic assessments. The chief environmental risk is climate change, but the risks of nuclear power, of ever-rising energy imports, and of excessive economic costs are addressed as well. In these low or minimum risk (MINR) scenarios, the efficiency, cogeneration, and renewable resource potentials are mobilized beyond economically cost-effective levels, i.e., *at* the specified implementation fraction, subject only to technical constraints such as requirements for dispatchability within the utility supply system.

A comparison of the least cost and low risk scenarios is the subject of other publications. This summary focuses on IPSEP's low-risk scenarios, which provide important insights into the question of resource sufficiency for achieving climate protection. Can the carbon targets for the EU be realized while phasing out nuclear power? What are the consequences for gas imports? And what cost premiums, if any, are associated with such an environmentally oriented strategy relative to a business-as-usual sscenario that pays no heed to mitigating global warming pollution?

Table 1 shows carbon emissions for IPSEP's MINR 50%, 65/50%, 75%, and 100% cases, combined with a nuclear phase-out or moratorium. There is a world of difference between these energy futures and those of the Energy Directorate. In the 100% case, carbon emissions drop fully 50 percent below 1990 levels. Reaching a 30 percent target for 2020 can be done with three quarters of Europe's clean energy potentials even if nuclear power is completely phased out at the same time. And, as discussed further below, cutting carbon emissions by these amounts can be done in a manner that is economically profitable.

Clearly, these propositions merit detailed scrutiny. We begin with a brief summary of the scenarios of the European Energy Directorate. From there, we examine the various low-carbon resources that are missing in the scenarios of the Energy Directorate. We then turn to IPSEP's economic analysis, and finally, we briefly review the current policy deficits that are preventing a timely transition to a sustainable energy future in the EU.

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3. Early scenario results were limited to five countries of the European Community including Germany in its pre-unification borders, and used 1985 as a reference year (Krause et al. 1994). The present report summarizes updated findings for the EU-15 using 1990 as a base year.

SCENARIOS OF THE EUROPEAN ENERGY DIRECTORATE

Conventional Wisdom

The Conventional Wisdom (CW) scenario of the Energy Directorate articulates expected outcomes under current national policies, which are often fractured along different objectives and national approaches. By definition, conventional wisdom does not incorporate new policies and measures to address global climate change anytime during the period until 2020. The scenario also more or less maintains existing regulatory and market structures in the energy supply sector.

As a result, carbon emissions in the conventional wisdom scenario grow larger, not smaller. The Kyoto target for 2010 — equivalent to an 8 percent reduction below 1990 levels — is badly missed as emissions are 9 percent higher instead. Furthermore, no turn-around occurs in this trend after 2010, as emissions in 2020 are 14 percent higher than in 1990 (Table 1). As a further symptom of this failure to "kick the fossil habit," the EU's dependence on fossil imports rises by about half, from 48 percent of primary energy inputs in 1990, to 68 percent in 2020.

Hypermarket

The Hypermarket (HM) scenario depicts a world of unfettered globalization and free-market oriented developments. In the energy sector, that world translates not only into rapid completion of power and gas sector deregulation, but also into a laissez-faire approach to the environment. Currently existing energy taxes are reduced. GDP grows somewhat more rapidly, and so do energy services in transport.

The shift into gas-fired power generation is even more pronounced than in the CW scenario. Just about half of all added thermal capacity is in the form of gas-fired combined cycle plants. Capital-intensive investments in new reactor capacity largely go into hiatus until the end of the scenario period, when a resurgence occurs. In 2020, additional generation from new renewables is 25 percent lower than in CW, indicating a loss of momentum for these innovation-prone generating technologies.

New policy measures to remove market barriers now impeding demand-side energy efficiency, such as energy efficiency standards and financial incentives programs, never get off the ground. Efficiency improvements beyond those of the conventional wisdom scenario occur mainly in the industrial sector, where accelerated growth and structural changes induce a somewhat faster turnover of capital stocks and lower energy intensities.

Just as in the case of the CW scenario, unfettered reliance on markets leads to failure in the area of climate change prevention, only more so. Carbon emissions in 2010 are 12 percent higher than in 1990, and 17 percent higher in 2020 (Table 1 above). Import dependence also worsens further.

Forum

In the Forum (FO) scenario, the same higher growth is achieved as in the Hypermarket scenario, but globalization and environmental pressures prompt new forms of collective public action, including energy policy measures to reduce carbon and other greenhouse gas emissions. In particular, the scenario includes a progressively rising energy/carbon tax, reaching $30/bbl oil in 2020.

The main effect of the tax is to substantially shift the composition of energy supplies. In power generation, a much greater contribution now comes from non-fossil energy sources. However, this is mainly the result of nuclear investments, which are exempted from the tax along with biomass and other renewables. Total nuclear capacity in 2020 increases by half and is twice that of the conventional wisdom and hypermarket scenario — and twice as large as that for renewables-based electricity sources.

While new power generation from renewables is dwarfed by new reactor capacity, the share of renewables in total year 2020 power production does increase significantly relative to both the CW scenario (plus 20 percent) and the HM scenario (plus 33 percent).

In the area of energy intensity on the demand side, there is little further progress. Because of reduced demand for fossil fuels, pre-tax prices for fossil imports remain flat. As a result, energy prices for consumers and firms rise only moderately above those of the Hypermarket scenario, despite the imposition of an energy/carbon tax. Unavoidably, improvements on the demand-side are minor because price signals are a relatively ineffective tool for influencing final energy demand, and even more so when price changes are modest. Overall, the energy/GDP ratio declines by 9 percent relative to the CW scenario (5 percent relative to HM).

The Forum scenario results in year 2010 carbon emissions that are 6 percent below 1990 levels — not quite sufficient to reach the Kyoto reduction target of 8 percent. In 2020, carbon emissions are 11 percent below 1990 levels (Table 1).

Discussion

The scenarios of the European Commission establish several important points. First, the Forum scenario illustrates that both within the 2010 and the 2020 timeframe, the European Union can cut carbon emissions below 1990 levels. Furthermore, the Energy Directorate finds that such reductions could be achieved without in any way degrading economic growth.

Second, as observed in the Energy Directorate report itself, blind reliance on laissez-faire deregulation and market forces is at odds with a balanced pursuit of European environmental, energy security, and technological competitiveness objectives. Neither the Conventional Wisdom nor the Hypermarket scenario offer entries into a sustainable development transition for the European Union.

Beyond these important contributions, three important criticisms must be made. First, the DG XVII analysis is technologically grossly incomplete. It fails to account for the hundreds of demand-side efficiency technologies that form the backbone of energy productivity improvements, and it is also lacking in its assessments of cogeneration and renewable options. Second, the study wrongly implies that in order to avoid the danger of global warming, Europe will have to accept the threat of reactor accidents and other risks of nuclear power. Third, the Energy Directorate's analysis is lacking in the area of economics: nowhere does the DG XVII report quantify how the total economic cost of energy services differs in each scenario.

The result is not only a myopic perception of energy choices or a failure to identify environmentally sustainable evolutions for the energy system. Like most official energy policy conceptions, the Energy Directorate fails to perceive how a low-carbon energy strategy could actually enhance Europe's technological and economic competitiveness.

This is where the IPSEP study comes in.[4] Using the same economic growth parameters as the Hypermarket scenario, it integrates the potentials of demand-side productivity, cogeneration of heat and power, and renewable energy sources into a cost-cutting energy-economic strategy for the European Union. This strategy rests on three technological pillars:

1. Policies that improve the markets for investments in more efficient appliances, lights, machinery, vehicles, and buildings yield large economic productivity gains: typically, the cost of energy saved is only a fraction of the cost of additional energy supplies.

2. The cogeneration of heat and power adds further energy efficiency gains on the supply side, at zero to slightly negative net cost.

3. Though most renewable options will initially be significantly more expensive than conventional supply technologies, their suitability for mass manufacturing and flexible siting allows for large and rapid improvements in both costs and performance. The point in time when cost-effectiveness will be reached can be advanced through proven policies for creating threshold markets.

Using these insights, the IPSEP scenarios leverage profitable investments in more energy-efficient end-use technologies to pay for the faster market introduction — and with it, faster reductions in cost — of renewable energy sources.

This one-two-punch approach of using the gains from energy productivity investments to buy down the costs of innovation-prone renewable technologies is the backbone of a profitable, competitiveness-enhancing sustainable energy strategy for the European Union.

4. The work summarized here is an update of an earlier analysis using the 1985 base year and covering five EU countries.

II. Low Carbon Resource Options in the EU

Increasing Efficiency in Energy-Using Equipment

Some believe that as a result of the two oil price shocks of the 1970s, most of the low-hanging fruit in the tree of energy savings have long been picked, and that further improvements are now limited and/or expensive. In fact, the potential for energy efficiency improvements has expanded along with the economy and has grown cheaper, as a result of rapid technological advances but limited on-the-ground market implementation.

Resource Potentials

Based on an analysis of more than 300 efficiency measures in more than 90 applications, the IPSEP study finds that on average, Europe's projected consumption of electricity, gasoline, heating fuels, and the variety of other final energy forms could be cut in half using only presently available technologies for improving buildings, vehicles and equipment. Moreover, this doubling of final energy productivity is obtained *after* accounting for any efficiency gains that are already included in the scenarios of the Energy Directorate, i.e., those that result simply from the routine replacement of old equipment with more efficient — but far from optimal — standard new equipment. Table 2 summarizes the key figures.

Buildings

In the EU, fuel use in buildings is heavily dominated by space heating. In deriving the technical savings potential, it is assumed that new buildings will reflect state-of-the-art passive solar low-energy and zero-energy technology, which now offers savings of 75-95 percent relative to conventional construction. Because existing buildings dominate energy use and are replaced or completely reconstructed only at a small annual rate, total savings are shaped strongly by the retrofit potential, which is more limited than feasible savings in new buildings. However, when they are being remodeled anyway, existing buildings can be retrofitted with state-of-the-art insulation, ventilation, and window technologies that reflect not only modern demands for comfort, but also for a healthy indoor environment. All in all, the savings potential in fuel use for heating buildings is an estimated 48 percent of year 2020 demand (IPSEP study, Part 5).

Even larger average percentage savings can be realized in electrical equipment used in the domestic and commercial sector. The various household appliances, computers, office equipment, and lighting and ventilation systems offer an enormous potential for improvement in Europe. Best technology can cut year 2020 electricity consumption by three quarters here, equivalent to a fourfold increase in the productivity of electricity use (IPSEP report, Part 3B). With electrical equipment typically lasting ten to fifteen years in Europe, and with most technologies already commercially available, the majority of these savings can technically be realized by 2010. On a weighted average basis, year 2020 fuel and electricity use in this sector can be cut by 54 percent.

Transport

The potential for improvements in the transport sector is similarly large. Here, automobiles strongly dominate the picture. The technical potential developed in the IPSEP analysis is based on a fleet-average automobile fuel consumption of 2.5 liters per 100 km in 2020. Advanced hypercar concepts that were not included in the IPSEP estimates would cut fuel consumption in half again.

This roughly 70 percent improvement over the current fleet is far larger than the 25 percent improvement that was recently agreed upon as a target by the European automobile manufacturers. To reach higher efficiency levels on a fleet average basis by 2020, manufacturers would have until about 2010 to bring new vehicles to the targeted performance level, since cars roughly turn over every ten years. Hybrid and electric cars approaching or even exceeding a fuel efficiency of 2.5l/100 km are becoming commercially available already now, and vehicles using highly energy-efficient fuel cells have been announced for 2005 or so by various major manufacturers.

Energy efficiency improvements in the next largest consumers of transport fuels — the ever-increasing fleet of trucks — are less dramatic but still large, and so are those in airplanes. On a weighted average basis, Europe's savings potential from efficient transport technologies is calculated as 51 percent in the IPSEP study (Part 4).

Table 2: Potentials for energy efficiency gains in the EU-15, year 2020

	EC/DG XVII Hypermarket HM final energy	IPSEP Technical potentials Final energy savings MINR 100% relative to HM scenario	
	Mtoe	Mtoe	%
Electricity (all sectors)	250	131	-52%
Transport, non-electric	378	194	-51%
Non-electric energy, industry and buildings	541	248	-46%
Total final energy	**1169**	**572**	**-49%**
Industry	340	138	-41%
Transport	394	195	-49%
Domestic & Commercial	435	238	-55%

Industry

In industry, technological advances have brought major energy efficiency improvements, especially in the steel, chemical, paper, and other primary materials industries that strongly dominate industrial energy use. Recycling, advanced materials, and more material-efficient designs can add to these savings. If fully implemented, this technological know-how would cut the industrial fuel consumption and carbon emissions of the Hypermarket scenario by close to half. Unrealized opportunities also remain to improve existing industrial plants, as demonstrated by recent voluntary agreements with various industry sectors in several European countries.

Contrary to what many believe, a significant efficiency potential also exists in electrical applications, both in industrial motor drives for pumps, compressors, fans, machine tools, robots, and other devices, and in various electrotechnology applications such as heat pumps, electric steel furnaces, etc. While electrotechnologies can often save primary energy relative to non-electric processes, they exhibit a range of efficiency levels themselves, making further improvements feasible. On a weighted average basis, the IPSEP study finds a 40 percent savings potential for industrial fuels and electricity use (Part 6).

Conventional Scenario Shortfalls

Fully 84 percent of Europe's efficiency technology resources remain untapped in the Energy Directorate's supposedly more environmentally oriented Forum scenario (see Figure 3, Short Summary above). In buildings and transport, the scenario realizes only an eighth of the technical-logistic potential identified in the IPSEP study. In industry, about 30 percent is realized.[1]

1. The results for industry are not quite comparable on account of some differences in the sectoral mix of industrial output. Also, the transport sector efficiency improvements assumed in the DGXVII scenarios are subject to some interpretation. However, these uncertainties are swamped by the order of magnitude difference in projected and potential energy intensities in the EU.

COGENERATION

Opportunities for reducing carbon emissions through increased energy productivity are not limited to the demand side. They also exist on the supply side, notably in the area of fossil-fired power generation. The main options are advanced combined cycle or gas turbine plants, and the cogeneration of heat and power (CHP or cogen) using such plants as well as internal combustion engines and fuel cells. The Commission scenarios fully incorporate the "flight into gas" that is occurring on account of the low capital costs, rising fuel efficiency, and short lead time of combined cycle plants. However, the DG XVII scenarios are sorely lacking in the area of cogeneration.

Gas-fired cogeneration plants reduce carbon emissions in two ways: first, the waste heat from thermal power generation is used to heat buildings and industrial processes, rather than being dumped into rivers or the atmosphere. Second, heat generated in gas- fired plants usually displaces heat obtained from a higher-carbon mixture of coal, oil, and gas in buildings or industrial processes. Depending on what type of conventional plant and what mix of heating fuels is being displaced, gas-fired cogeneration can cut carbon emissions per unit of electricity by up to 70 percent.[2] The technology's environmental benefits also include lower acid rain emissions. Last but not least, gas-fired cogeneration is easily as cheap or cheaper than power from gas-fired central stations.

Resource Potentials and Conventional Scenario Shortfalls

According to the Hypermarket scenario, some 300 GW of new and replacement fossil-thermal generating capacity is to be built in the EU in the 2000-2020 period, and about 30 GW of biomass-fired capacity. Technically, almost all of this additional thermal capacity could be built as cogeneration plants.[3]

Focusing only on plants to be built in 2000-2020, Table 3 shows estimates of the corresponding potential for reductions in year 2020 electricity sector carbon emissions. With 75-90 percent of additional capacity built as cogeneration plants, combined heat and power would contribute 58-69 percent of total thermal power generation in 2020. Carbon emissions would be cut by about 290-350 Mt CO_2. Even at the maximum level, which would cut power sector carbon emissions in the Hypermarket scenario by about 30 percent, only about half of the CHP-suitable demand for heat would be provided by cogeneration plants (IPSEP study, Part 3C).

Again, the scenarios of the Energy Directorate are not anywhere close to these potentials. In the Hypermarket scenario, the cogen share of 2000-2020 thermal capacity additions is a mere 16 percent, and less than a quarter of feasible carbon savings are realized. In the Forum scenario, the contribution rises to 24 percent of 2000-2020 thermal additions. (Absolute carbon reductions are smaller in Forum than in Hypermarket because much less power comes from fossil-thermal generation and because cogeneration replaces a less carbon-intensive generating mix).

These differences aside, both Energy Directorate scenarios fall far short not only of the technical potential, but also of the cogen potentials realized by policy leaders in Europe. For example, in the Netherlands, virtually all new fossil-thermal capacity additions are now based on gas-fired cogen technology. And in Denmark and Finland, where cogeneration has long been given preference, the share of CHP in total power production is approaching 50 percent.

RENEWABLE ENERGY SOURCES

In 1995, the European Union obtained about 7 percent of total final energy from renewable sources. The two major resources were biomass fuels for heating and hydro electricity. In the power sector, the EU produced about 330 TWh of renewable electricity. About 90 percent of this total came from long existing hydro capacity. The remaining figure for non-hydro or new renewables came mainly from biomass waste plants, followed by wind power generation and by geothermal in distant third place. Output from photovoltaics and other solar-electric schemes was insignificant. In non-electric applications, solar thermal collectors and geothermal heat contributed less than one percent to final energy use.

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2. The carbon benefits are even greater when burning biomass in a cogeneration plant. Here, electricity is produced without net carbon emissions, and in addition, fossil fuels are displaced on the heating side. The result is that each unit of electricity is obtained not only at a reduced carbon burden, but at a net carbon credit. For this reason, even a limited amount of biomass cogeneration can produce a significant additional carbon emission benefit (see Part 3C of the IPSEP study).

3. Thermal generation refers to fossil-fired and biomass-fired thermal power stations.

Table 3:
Potential for reducing year 2020 EU-15 carbon emissions through cogeneration of heat and power

	Units	Actual 1990	Hypermarket (HM) Scenario 2020	Forum (FO) Scenario 2020	HM w. 75% of 2000-2020 new fossil capacity as cogen	HM w. 90% of 2000-2020 new fossil capacity as cogen
Total thermal electricity generation	**TWh**	**1159**	**2473**	**1557**	**2473**	**2473**
Total new thermal capacity (2000-2020)	GW		330	237	330	330
of which cogen capacity (fossil & biomass)	GW		52	56	249	302
Cogen electricity output	**TWh**	**137**	**340**	**355**	**1426**	**1715**
Share of total thermal generation	*fraction*	*0.12*	*0.14*	*0.23*	*0.58*	*0.69*
C reductions from cogen	**MT CO2**	**17**	**75**	**52**	**290**	**349**
C-savings potential realized	*Fraction*		*0.22*	*n.a.*	*0.83*	*1.00*

Resource Potentials and Conventional Scenario Shortfalls

The various estimates for Western Europe's renewable resources are shown in Tables 4 and 5. The main differences are in the area of electricity generation. According to the EC White Paper on renewable energy sources (EC 1997a), the output from hydro stations in the EU-15 could be raised to 360 TWh by 2020. Non-hydro renewables are given a potential of 330 TWh, equivalent to a tenfold increase over current levels. Three quarters of this potential is ascribed to biomass-fired generation using both wastes and biomass tree crops. The Forum scenario is mainly based on these estimates.

The IPSEP study adopts the Forum figures for hydro, but finds a significantly larger potential for non-hydro renewables: 500 TWh instead of about 300 TWh in Forum. The potential for biomass is higher by a third, and the wind potential is larger by close to a factor of two. The higher figure for wind reflects the same restrictive assumptions regarding on-shore siting of wind generators as the Commission's White Paper. However, it includes offshore wind resources and also incorporates anticipated technological advances that extend cost-efficient generation to lower-speed wind regimes.

Lastly, IPSEP identifies a significant, 70 TWh resource potential from solar photovoltaics. This is the output that will result in 2020 if European PV installations keep expanding at the current average global rate of growth (close to 40 percent) over the period until 2020. To put this assumption into context, the recently inaugurated German PV program will grow PV capacity in that country by more than 60 percent per year over six years. Overall, renewable resources in the Forum scenario are comparable to those in IPSEP's MINR 50% case.

In the Energy Directorate's Hypermarket scenario, the share of renewables in total final energy use reaches 10 percent in 2020, up from 6.5 percent in 1990 (Table 5). Though this is a significant increase, the scenario realizes only 25 percent of the non-hydro electricity potential identified in the IPSEP study. In the Forum scenario, renewables rise to 13 percent of total final energy use. This is equivalent to a doubling of the 1990 share. In electricity generation, the Forum renewables contribution rises to 660 TWh, supplying 21 percent of electricity use. Some 60 percent of the non-hydro potentials identified in the IPSEP study are included here.

A doubling of the renewables share may sound impressive, but when considering the small starting percentages in the base year, it is clear that even in the Forum scenario, the role of renewables remains far from what a sustainable energy system would require. A more complete mobilization of Europe's wind, biomass, and solar resources can improve results, but energy efficiency gains are most important in raising the renewables share further.

This dynamic is illustrated in Table 5. If the full EU demand-side potentials are combined with the full renewables potentials, as in IPSEP's MINR 100% scenario, the total share of renewables jumps almost fourfold relative to 1990, to 25 percent of final energy use. In the electricity sector, renewables just about reach the 50 percent mark. All in all, it is clear that renewables can contribute far more than depicted in the scenarios of the Energy Directorate. Arguably, proposals for a doubling of the renewables share in the EU are an insufficiently ambitious target when demand-side efficiency is taken into account.

OTHER OPTIONS

A number of other technology options exist for cutting EU carbon emissions and other global warming pollutants. In the energy sector, these include nuclear power, fossil fuel decarbonization, scrubbing of carbon dioxide from stationary sources, sequestration through build-up of sinks, and reductions in methane releases from coal beds and natural gas systems. Of these options, only nuclear reactors are now widely deployed in the EU. The future role of nuclear power is discussed on pages 13-15.

Table 4:
Comparison of renewable electricity potential and scenario estimates for the European Union

	Renewable power resources in the EU-15 (TWh/yr)					
	Actual	Potential		Scenarios		
		IPSEP Logistic/achievable	EC White Paper	DG XVII Forum	DG XVII Hypermarket	IPSEP MINR 65%/50%
	1995	2020	2010	2020	2020	2020
Biomass	21.7	323	237	237	101	210
Wind	5.3	104	85	59	24	68
Solar	0.0	70	3	2	1	46
Geothermal	3.1	5	6	4	2	3
Subtotal non-hydro	**30**	**502**	**331**	**305**	**129**	**326**
Index (IPSEP potential = 1.00)		*1.00*	*0.66*	*0.61*	*0.26*	*0.65*
Hydro	**303**	**356**	**360**	**354**	**352**	**360**
of which new in 1990-2020		96	100	94	92	100
Total renewable electricity	**333**	**858**	**691**	**659**	**481**	**686**
Index (1995 = 1.00)	*1.00*	*2.58*	*2.08*	*1.98*	*1.44*	*2.06*
		1.00	*0.81*	*0.77*	*0.56*	*0.80*

(1) For IPSEP technical potentials, see Part 3D. For European Commission White Paper, see EC 1997a.

Table 5:
Contribution of renewables to EU-15 final energy supplies, Scenarios for 2020

	Fraction from renewables in 2020			
	DG XVII		IPSEP Productivity scenarios	
	Hypermarket	Forum	MINR 65%/50%	MINR 100%
Total final energy use, mtoe	**1169**	**1076**	**901**	**596**
Final energy from renewables, mtoe	**111**	**138**	**136**	**152**
Final electricity from renewables	*14%*	*21%*	*26%*	*49%*
Transport sector biofuels	*9%*	*13%*	*14%*	*27%*
Other: biomass fuels, solar and geothermal heat	*8%*	*9%*	*10%*	*14%*
Renewables share, all sectors	***10%***	***13%***	***15%***	***25%***
Index percentage contribution	1.00	1.35	1.58	2.67
Index absolute contribution	1.00	1.24	1.22	1.36

III. What Role for Nuclear Power?

Perhaps the most unrealistic aspect of the "business-as-usual" scenarios of the Energy Directorate is the assumption of a resurgence for nuclear power. For many years now, new reactor projects have been canceled outright or postponed indefinitely throughout the European Union. Most EU countries operate under de facto or explicit moratoria on nuclear construction, and some have plans for phasing out all nuclear generation. The only country where a significant number of new reactors might still be completed is France. And even there, the pro-nuclear consensus is under siege.

From all this, it is clear that most Europeans do not wish to trade one environmental risk, i.e., global warming pollution, for another, i.e., the multiple dangers associated with the nuclear power enterprise. Though not everyone may share these concerns, one of the low-carbon strategies of greatest interest for Europe is one in which cuts in fossil fuel consumption go hand in hand with a phase-out of nuclear power. Because such a scenario would appear to make carbon reductions principally more difficult, it also represents an instructive analytical limiting case.

Nuclear Power in the Energy Directorate Scenarios

The failure of current nuclear technology to compete against less capital-intensive options in a deregulated power market is at least partially acknowledged by the European Commission. In the Hypermarket scenario, reactor output drops from 720 TWh in 1990 to 534 TWh in 2020. The decline in output partly reflects the fact that most existing reactor capacity will have to be decommissioned by 2020. In the DG XVII analysis, production from pre-1990 reactors would fall to somewhat less than 300 TWh in 2020.

However, in the Hypermarket scenario some 30 new reactors are to be constructed between 2010 and 2020, raising nuclear output back up by about 240 TWh. Presumably, these would be reactors of a somewhat improved type that is now under development. In the Forum scenario, new reactor construction in the 2000-2020 period would more than triple: Some 30 new reactors would be completed already by 2010 (which means they would have to be largely under construction now), and more than 100 reactors in the following decade — or about one completion per month, year after year.

Options for a Low-Carbon Nuclear Phase-Out

In the Hypermarket scenario, carbon emissions from Europe's electricity system rise 25 percent above 1990 levels. By contrast, the nuclear-intensive Forum scenario lowers power sector emissions by roughly a third below 1990 levels. Could nuclear power be phased out while matching these results in the power sector itself, or while achieving and transcending the Kyoto targets in the economy as a whole — without sending gas requirements through the roof? The answer is yes. It all depends on the resource strategy being chosen. Table 6 shows the power sector resource mix for the scenarios of the Energy Directorate and then illustrates several options for realizing a nuclear moratorium (no new construction) and a complete nuclear phase-out by 2020.

Supply-Side Approach

Let us first try a supply-side approach and impose an indefinite nuclear moratorium starting in 2000 (column 4 in Table 6). This leaves some 345 TWh of nuclear electricity in the mix for 2020, most of it in France. The output from reactors that were supposed to be built after 2000 represent about 190 TWh, and this electricity must now come from somewhere else.

Using a supply-side approach, we might adopt the level of renewable power generation envisioned in the Forum scenario. This substitution can be augmented by less use of coal and more gas in new fossil powerplants, again as in the Forum scenario. Finally, we raise the cogen share of year 2000-2020 thermal capacity additions to 75 percent (see also Table 3 above). This modification of the Hypermarket scenario is shown in column 4 of Table 6.

With these modifications, a nuclear moratorium would still yield a roughly 10 percent reduction in power sector carbon emissions below 1990 levels. At the same time, the above strategy would fall far short of the reductions realized in the Forum scenario, and in the economy as a whole, the shortfall vis à vis the Kyoto target would widen. With a complete nuclear

Table 6:
Phasing out nuclear power while reducing carbon emissions: possibilities for the EU-15

	Electricity mix, natural gas requirements, and carbon emissions						
	with nuclear growth			***with substitution of nuclear power***			
	Actual EU-15 1990	Scenarios Energy Directorate HM 2020	 FO 2020	HM w. FO renew. & FO fossil mix Mod. hi cogen & moratorium new nuclear	HM w. FO renew. & FO fossil mix High cogen & phase-out all nuclear	IPSEP 50/50% svgs pot 50% new el. ren. Mod. hi cogen & moratorium new nuclear	IPSEP 65/50% svgs pot 65% new el. ren. High cogen & phase-out all nuclear
	1	2	3	4	5	6	7
Gross generating requirements, TWh	**2141**	**3384**	**3119**	**3384**	**3384**	**2496**	**2229**
Nuclear generation	720	534	1142	345	0	345	0
Demand-side efficiency (gen. equiv.)	0	0	265	0	0	888	1155
Hydro&other renewables incl. biomass cogen	276	481	659	659	659	603	663
Fossil-thermal generation incl. cogen	1144	2369	1318	2380	2725	1547	1566
Cogen share of 2000-2020 new thermal capacity		*0.16*	*0.24*	*0.75*	*0.93*	*0.75*	*0.94*
Net C-emissions el. generation, Mt CO2	**948**	**1129**	**580**	**865**	**974**	**598**	**584**
Index (1990 = 1.00)	*1.00*	*1.19*	*0.61*	*0.91*	*1.03*	*0.63*	*0.62*
Index (FO 2020 = 1.00)			*1.00*	*1.49*	*1.68*	*1.03*	*1.01*
Gas requirements all sectors, Mtoe	**214**	**567**	**415**	**528**	**561**	**429**	**430**
Index (HM 2020 = 1.00)		*1.00*	*0.73*	*0.93*	*0.99*	*0.76*	*0.76*
Index (FO 2020 = 1.00)			*1.00*	*1.27*	*1.35*	*1.03*	*1.04*
Carbon emissions all sectors, MtCO2	**3166**	**3699**	**2817**	**3434**	**3543**	**2643**	**2639**
Index (1990 = 1.00)	*1.00*	*1.17*	*0.89*	*1.08*	*1.12*	*0.83*	*0.83*

phase-out (fifth column in Table 6), the same purely supply-side strategy becomes even more limiting. Now, power sector carbon emissions could not even be stabilized at the 1990 level, even though 90 percent of new thermal capacity is based on cogeneration. Moreover, gas consumption reaches the price-inflating levels of the Hypermarket scenario.

Integrated Approach

These results explain why some analysts believe that nuclear power is needed for climate stabilization. However, a very different picture arises if we look at the integrated (supply-side plus demand-side) strategies shown in the sixth and seventh column of Table 6, which are taken from the IPSEP study. These cases illustrate that both a moratorium and a complete nuclear phase-out could be realized while pushing year 2020 power sector carbon emissions by more than a third below 1990 levels.

In the moratorium case, the cogen share in 2000-2020 thermal capacity additions rises to 75 percent as before and the contribution from new renewables is similar as well, at 50 percent of IPSEP's potential. But now, 50 percent of Europe's energy productivity potentials are implemented both in electric and non-electric applications (MINR 50/50 case).

In the phase-out case, almost all new thermal capacity is built as cogen plants, and the implementation fractions for electric end-use efficiency and new renewables are raised to 65 percent. In non-electric applications, the implementation fraction remains 50 percent (MINR 65/50 case).

These resource strategies match the year 2020 emission cuts of the Forum scenario in the power sector itself; they also result significantly larger carbon cuts in the economy as a whole — 17 percent below 1990 levels. What is more, they also succeed in limiting gas consumption to Forum levels. Thus, a phase-out of nuclear power does not have to be in conflict with limiting Europe's dependence on gas.

Because efficiency and renewables potentials are only partially implemented, both scenarios leave ample room for less than perfect policy programs. Conversely, larger reductions could be achieved with more aggressive implementation efforts in the area of energy efficiency. Notably in the automobile sector, larger emission reductions could be straightforwardly implemented. Again assuming an accelerated retirement of existing reactors by 2020, a year 2020 reduction target of 30 percent could still be reached with a roughly 75 percent implementation of electrical and fuel efficiency potentials (see also Table 1 on page 2).

IV. Economics of a Low-Carbon Energy Future

So far, we have shown how from a technical and logistic[1] point of view, Europe's carbon emissions can be lowered by as much as 50 percent below 1990 levels. But what about the costs? After all, the main explanation for the weakness of the Kyoto protocol, and the driver behind the ongoing negotiations over loopholes and the so-called flexibility mechanisms, is the notion that reducing fossil fuel use will be costly.

Various preliminary analyses undertaken by different Directorates of the European Commission and by national governments have convinced most European policy makers that at least for the current targets, this is not the case. In the EU, the economic impacts of Kyoto are widely perceived as at worst minor, and are seen as more than justified by the benefits of climate protection.[2]

However, the European Commission has yet to complete an in-depth economic analysis of a strategy that cuts carbon emissions primarily through investments in energy productivity. In some sense, this is not surprising, since as of now, the Energy Directorate's MIDAS modeling system lacks the database and capability for assessing the all-important technological and economic opportunities on the demand-side. Without a detailed quantification of feasible energy productivity gains from demand-side investments in more energy-efficient buildings, vehicles, appliances, and other equipment, a sound assessment of the costs and benefits of mitigating carbon emissions is simply impossible.

Modeling Issues

The models and input data used by the Energy Directorate are incomplete in another respect: they fail to capture most of the effects of climate protection policies on the rate of technological innovation or "learning by doing." This feedback effect is crucial for economic assessments, since part of climate-policy induced innovation is learning to produce new low-carbon technologies at lower cost.[3]

The one important policy feedback that is captured in the work of the Energy Directorate is the reduction of pre-tax prices for fossil fuels as the demand for these energy carriers declines. Even though absolute fuel price forecasts are inherently uncertain, econometric modeling systems such as that used by DG XVII can provide useful estimates of price differences for different levels of demand (see below).

For now, it is important to observe that contrary to what many policy makers assume, the above cost-reducing feedbacks, and the various opportunities for profitable energy productivity investments, have *not* already been taken into account in existing studies — either in Europe or elsewhere — with serious consequences: Studies that fail to capture these elements will tend to report significant economic costs when climate protection can bring significant economic benefits — even before considering the value of avoided climate damage.[4] The same goes for the cost of phasing out nuclear power.

In the remaining sections, we briefly discuss the economic findings from the IPSEP study for the EU. This study was designed to avoid the above problems through several analytic features: (1) it includes not only detailed cost and resource data for energy supply options, but also for demand-side efficiency measures; (2) it incorporates not only policy-induced feedback effects on fossil energy prices, but also on technology costs; (3) it accounts not just for investment costs, but also for the costs of policy implementation programs; (4) it calculates the total cost of energy services not only for conventional supply-oriented strategies, but also for integrated demand-side plus supply-side strategies; and (5) it shows what happens to carbon emissions and costs not

1. With logistic limitations we mean the rate of capital stock turnover, and the time needed for policy programs to ramp up and for efficient end-use technologies to penetrate into the capital stock.

2. For a review of European mitigation cost studies, see Krause (1996).

3. While the analysis of DG XVII does account for improvements in the cost and performance of some low-carbon technologies, such as biomass-fired generation, a comprehensive treatment is lacking, especially for the all-important energy productivity technologies on the demand side.

4. In recognition of the limitations of its own modeling system and demand-side efficiency database, the Energy Directorate has refrained from reporting estimates for the total cost of energy services in its scenarios.

only for one preferred forecast, but assuming different levels of policy adoption and effectiveness. While further analytic improvements are needed and underway in each of these areas, our results so far show dramatic deviations from conventional wisdom.

Profits from Energy Productivity

The economic superiority of demand-side investments over supply-side investments is pronounced (Table 7). Most — but not all — efficient equipment has a higher first cost. The annual "mortgage" payment or levelized cost for this extra investment, divided by the quantities of electricity, gasoline, or heating fuels saved each year, is the cost of saved energy. In IPSEP's analysis, this cost is further adjusted to reflect administrative costs for policy programs.

Table 7 shows that even *before* considering policy-induced feedback effects (left set of columns), a unit of final energy saved costs about a third less on average than a unit supplied. Indeed, most investments pay back in a few years or even months — long before the energy-using equipment is worn out. This is how energy productivity profits come about.[5]

Of course, not all technically feasible measures are cost-effective, and there are also differences by sector and application. Cost-effectiveness is most pronounced in industry, where new more energy-efficient processes often save not only energy, but also labor, materials, and other inputs. Smarter use of energy-intensive materials works the same way. For a number of processes, the cost of energy savings is negative — energy savings are obtained while reducing the sum of capital, labor, and non-energy operating costs.

In the transport sector, the cost of high efficiency automobiles is rapidly declining as hybrid vehicles are entering the market. Yet even at today's high niche market prices, large improvements are cost-effective against European after-tax fuel prices.

This cost-effectiveness on the demand-side is in marked contrast to the situation on the supply side, where based on today's prices, new renewable generating options cost about a third more per kWh than conventional fossil-based supplies, even assuming year 2020 fuel prices.

Feedback Effects on Technology Costs

Market experience with innovations in energy supply and energy efficiency technologies over the last thirty years has shown that the costs of small-scale, modular technologies such as wind turbines, photovoltaics, fuel cells, and a myriad of efficiency measures can drop dramatically with production experience and with increased market share. For example, since the late 1970s, wind turbine and PV costs have been falling at a compounded rate of 15 percent per year in real terms. Meanwhile, the costs of newly completed nuclear reactors have continued to rise. By now, they significantly exceed the costs of wind power from commercially developed sites.

Even more pronounced cost reduction effects are being observed on the demand side. For example, with the introduction of mandatory energy efficiency standards in the U.S. and Europe, the market price of required efficiency improvements in refrigerators has dropped to virtually zero. Here, technological innovation and economies of scale combine with the repositioning of energy efficiency in manufacturers' pricing strategies: with voluntary or mandatory performance standards, efficiency is no longer a high mark-up feature for a niche market, but an integral attribute of products designed for the highly competitive mass market.

A similar dynamic can be observed in the auto industry. Based on long-standing industry experience, the extra cost of hybrid and other high efficiency vehicles will fall dramatically once they are produced in the millions rather than in the ten thousands.

The right set of columns in Table 7 show how these dynamics play out in the IPSEP study, again using the MINR 65/50 case described in Table 6 above. Relative to the Hypermarket scenario, energy efficient devices gain a roughly ten-fold increase in market share. This pushes down the costs of improved demand-side technologies, cutting their average cost almost in half.

On the supply side, lower demand also leads to lower costs. Here, the average (pre-tax) price of final energy supplies declines by a quarter. Put another

5. See, e.g., Romm (1999). In Table 7, we use an all-economy rather than consumer perspective. We compare electrical end-use efficiency investments with marginal generating and T&D costs only, i.e., we exclude utility system fixed costs for transmission and distribution. Similarly, we show transport fuel prices net of automotive fuel taxes. We thus measure only the private internal costs of fuel consumption. Insofar as gasoline and other taxes serve to internalize various societal costs, our comparison significantly understates the cost-effectiveness of fuel efficiency.

Table 7:
Cost-effectiveness of energy efficiency and renewable energy investments before and after accounting for policy-induced feedbacks

	Low Carbon Resource in 2020 IPSEP MINR 65/50 mtoe/yr	**Levelized cost using a 5% real discount rate, in ECU'89/kWh**					
		Before policy feedbacks			*After policy feedbacks*		
		MINR 50% demand-side cost High	marginal supply cost High	Ratio efficiency/ supply High	MINR 50% demand-side cost Low	marginal supply cost Low	Ratio efficiency/ supply Low
Efficiency, by sector/application							
More efficient el. use, all sectors	85	1.8	3.9	*0.45*	1.1	2.8	*0.41*
More efficient fuel use in industry	52	0.8	3.0	*0.26*	0.4	1.9	*0.22*
More efficient fuel use in buildings	70	2.7	4.0	*0.67*	1.6	3.3	*0.49*
More efficient fuel use in transport	87	3.5	2.8	*1.24*	1.6	2.4	*0.69*
Total/average all applications	**294**	**2.3**	**3.5**	***0.67***	**1.3**	**2.6**	***0.48***
index efficiency costs (ex ante = 1.00)		*1.00*			*0.55*		
index supply costs (ex ante = 1.00)			*1.00*			*0.76*	
Electricity fr. new renewables	**35**		**5.3**			**3.1**	
index (ex ante = 1.00)			*1.00*			*0.59*	

1) Electricity supply price shown here is system average marginal cost of generation without T&D or general overhead.
2) Transport fuel prices exclude taxes.

way, demand-side costs decline twice as much as the costs of marginal supplies. As a result, the cost-advantage of demand-side investments grows even larger: They now beat supplies by a factor of two (Table 7).

The main factor bringing about lower supply costs is a drop in (pre-tax) fossil fuel prices on account of lower demand (see below). In the power sector, two other factors are important. First, lower demand means that relatively cheap existing supplies such as hydro power contribute a larger share to the generating mix, which brings down average supply costs. Second, the cost of new generating technologies also declines. This is especially pronounced for new renewables whose market in the MINR 65/50 case grows more than tenfold relative to 1990 levels (see Table 5 above).[6]

Feedback Effects on Fossil Fuel Prices

In the Hypermarket scenario, year 2020 fossil fuel consumption in the EU is 28 percent higher than in 1990. Coal use declines by half, while oil consumption is up 19 percent and gas consumption rises by 164 percent (Table 8).

Meanwhile, global fossil fuel consumption rises by 57 percent. Coal consumption is up 29 percent, oil consumption 40 percent, and gas use 132 percent. According to the modeling calculations of the Energy Directorate, this demand scenario would be accompanied by close to a doubling in oil and gas import prices for Europe, plus a modest increase in imported coal prices. Notably, the more than doubling of gas consumption in the envisioned "dash for gas" necessitates expensive new pipeline construction.

In the Energy Directorate's Forum scenario, which was formulated before Kyoto, it is assumed that the EU would pursue its emission reductions in a context of limited global cooperation and implementation of certain agreed-upon common actions. In the EU, year 2010 carbon emissions fall by 6 percent, i.e., close to the Kyoto target.

Carbon emissions in other OECD countries are also reduced below the baseline projection, though in a less decisive manner. In the U.S. and other non-European OECD countries, carbon emissions rise about 10 percent above 1990 levels, falling far short of Kyoto commitments. At the same time, technological spill-over through foreign investments and international trade and competition leads to a small slowing of the growth in carbon emissions in developing countries.

Despite these moderate assumptions on climate policy action, significant shifts in fossil fuel consumption occur. In the EU, year 2020 fossil fuel consumption now remains virtually constant at 1990 levels. Coal use is down 75 percent relative to 1990, oil consumption rises only 7 percent, and gas requirements increase by only 94 percent.

Globally, there is an 8 percent decline in year 2020 fossil fuel consumption relative to the Hypermarket baseline. World oil consumption is 10 percent lower. More than 70 percent of the global demand reduction arises from carbon reduction measures in OECD countries. About 30 percent of the total is contributed by the European Union alone.

In the energy market modeling of the European Commission, this context of OECD policy measures and global technological shifts, along with the slower growth in fossil fuel demand, has the result of keeping import prices for fossil fuels essentially flat at base year levels. The strong response of world oil prices to a roughly 10 percent reduction in demand is explained by a diminished monopoly pricing power on the part of OPEC. Prices are also flat for natural gas; though gas consumption still is up the most, the increase remains below the threshold where major new long-distance pipeline projects become necessary to supply the needs of the European Union.

Taking the primary consumption levels of the Forum scenario, we can calculate what the pre-tax EU fossil fuel bill would have been if prices had remained fixed at the level of the Hypermarket scenario. The difference between that bill and the one that actually applies in the Forum scenario is more than 100 billion ECU per year in 2020 alone, equivalent to 1.2 percent of projected EU-15 gross domestic product (gdp).

In the IPSEP scenarios, even larger fuel price drops are possible: In the case of oil, IPSEP's demand reductions are larger by a third, mainly due to new automobile technology not considered in

6. By 2020, new renewables end up being only about ten percent more expensive than power from advanced gas-fired plants, and they could well do better. A portion of this price drop would already be realized in the Hypermarket scenario (see Table 5 on page 12). In Table 9 on page 22, only a portion of the cost reduction in renewables-based electricity shown in Table 7 is counted as a policy-induced saving.

Table 8:
Year 2020 fossil fuel consumption: baseline versus alternative low carbon scenarios

	World			EU-15		
	DG XVII		*IPSEP*	*DG XVII*		*IPSEP*
	Hypermarket	Forum	MINR 65/50	Hypermarket	Forum	MINR 65/50
Primary energy, mtoe						
Coal, mtoe	3084	2794	2786	153	75	67
Oil, mtoe	4148	3720	3635	650	584	499
Gas, mtoe	3976	3747	3755	585	431	439
All fossil fuels, mtoe	11209	10261	10176	1389	1090	1005
Change rel. to HM, %						
Coal, change		*-9%*	*-10%*		*-51%*	*-56%*
Oil, change		*-10%*	*-12%*		*-10%*	*-23%*
Gas, change		*-6%*	*-6%*		*-26%*	*-25%*
All fossil fuels, change		*-8%*	*-9%*		*-22%*	*-28%*

the Forum scenario. Given the highly globalized nature of the automobile industry, European leadership would plausibly result in additional reductions in oil demand in the other OECD countries, and also would deliver more mobility with a smaller growth in oil consumption in the developing countries. California's leadership in tightening tailpipe emission standards illustrates the global effectiveness of such technology push initiatives.

Even without these and other plausible spillover effects, global reductions in oil demand rise from 10 percent in Forum to 12 percent in the IPSEP scenario (Table 8). Changes in coal and gas consumption are only slightly larger than in the Forum scenario. In total, the year 2020 contribution of the EU to the global slowing of growth in fossil fuel consumption would rise from about 30 percent in Forum to 40 percent.

In view of the considerable uncertainties surrounding fuel price estimates, no further downward adjustment in import fossil fuel prices is made in the IPSEP study. On the contrary, to be conservative, a somewhat more modest price drop from reduced global demand is assumed that results in 20 percent smaller year 2020 fuel bill savings than in the Forum scenario. With this conservatism, total savings from policy-induced decreases in fossil fuel prices are about 80 billion ECU per year in 2020.[7]

The Economics of a Combined Fossil and Nuclear Phase-Out

Just how the various costs and savings add up is illustrated in Table 9, which shows a comparison of the Energy Directorate's Hypermarket scenario with IPSEP's MINR 65/50 scenario for a nuclear phase-out by 2020.[8]

Power Sector: Gross Impacts on Electric Bills

The gross cost of a combined fossil and nuclear phase-out — i.e. the economic impact before accounting for policy-induced feedback effects — are best understood through a step-by-step examination of changes in the year 2020 resource mix, starting with the Hypermarket scenario.

We begin with the complete substitution of all 534 TWh of year 2020 nuclear power generation, relying purely on conventional fossil resources. In this first step, nuclear electricity is replaced with gas-fired generation. In Hypermarket, about 345 TWh come from capacity that is already operating before 2000, and 189 TWh comes from reactors completed after 2000. The economic impact of phasing out all reactors by substituting gas plants is mainly determined by the low operating costs of existing reactors relative to the gas-fired combined cycle plants replacing them. When eliminating all 345 TWh from reactors that were already running in 2000, this difference comes to about 11 billion ECU per year in 2020. Meanwhile, the additional gas-fired capacity raises power sector carbon emissions by 264 million metric tons of CO_2 (see Table 9). Now let us broaden our approach and bring to bear Western Europe's efficiency options, as illustrated previously in Table 6 above. Assuming that demand-side management policies are strongly pursued (but imperfectly implemented), we shift 65 percent of all year 2020 electricity-using equipment to best available efficiency levels. From the logistical point of view, the time frame of two decades for this market transformation is ample: over twenty years, most energy-using capital stocks go through more than one replacement cycle or, in the case of buildings, through at least one major overhaul. The resulting productivity gains cut generating requirements by 1145 TWh. The rise in gas-fired generation from the previous substitution becomes a reduction in the need for gas-fired or other fossil generation. Carbon emissions drop by 594 million tons in 2020 — far more than needed to offset the

7. Declining ex ante fossil fuel prices do not necessarily translate into incentives for greater consumption of fossil fuels. The demand for fossil fuels depends on ex-post prices, and these can be raised to the level of the base case or even above. As an example, the Energy Directorate's Forum scenario includes a progressively rising energy/carbon tax, reaching $30/bbl oil in 2020.

8. See also Table 6 above. We do not show here our separate analysis of a moratorium, the economics of which can be gleaned from Table 9. In the moratorium case, the extra generating cost of 13 billion ECU per year in 2020 from replacing existing reactors is eliminated. Considering first gross costs only, a moratorium on new construction could well bring a net benefit, since even a new version of capital-intensive reactors can be expected to produce electricity at higher costs than gas-fired cogeneration and advanced combined cycles (IPSEP 1994). Moving to net costs including policy feedbacks, these capital savings will be augmented by broadly the same fuel price, technology cost, and electric system savings that apply to the phase-out case.

Table 9: Ex ante and ex post costs of a carbon reduction strategy for the EU-15, year 2020

Electricity Production and Use	Year 2020 C reductions, costs, and benefits					
	Power generation EU-15 TWh/yr	C-emissions incl. cogen credits MtCO2/yr	Costs of energy services MtCO2/yr	Change in emissions 2020 MtCO2/yr	Unit cost of C reduction ECU/tCO2	Total cost impact 2020 B ECU/yr
1990 base year, power sector	2141	948				
2020 baseline HM scenario incl. cogen credits	3384	1129	249			
Power sector measures						
Phase out nuclear reactors	534	1400	260	270		11
Increase end-use efficiency (65% of tech. pot.)	-1155	802	240	-597	-53	-19
Increase gas-fired cogeneration	672	664	240	-138	-4	-0.6
Increase renewable generation	180	584	243	-79	23	2.6
Gross impact, all measures				-545	-12	-7
Policy-induced cost effects						
Lower efficiency and renewables costs						-15
Lower-cost resource mix at lower demand						-13
Lower fossil fuel import prices						-22
Total, electric end-uses in 2020	**2229**	**584**	**205**			
Net impacts, power sector measures				**-545**	**-106**	**-58**
Reduction (2020 HM = 100%)				*-48%*		*-23%*

Non-Electric End Uses	Year 2020 C reductions, costs, and benefits					
	Direct fuels use/DSE Substitution mtoe/yr	Carbon emissions EU-15 MtCO2/yr	Costs of energy services B ECU/yr	Change in emissions 2020 MtCO2/yr	Unit cost of C reduction ECU/tCO2	Total cost impact 2020 B ECU/yr
1990 non-electric final uses, base year	707	2218				
2020 non-el. final uses, HM scenario	917	2570	333			
Increase end-use eff. (50% of tech. pot.)	-189	2054	318			
Gross impacts rel. to HM scenario, 2020				-516	*-30*	-16
Policy-induced cost effects						
Lower efficiency and renewables costs						-36
Reduction of fossil fuel import prices						-58
Total, non-electric end-uses in 2020	**729**	**2054**	**224**			
Net impacts, non-electric applications				**-516**	*-213*	**-110**
Reduction (2020 HM = 1.00)				*-20%*		*-33%*

	mtoe	MtCO2/yr	B ECU/yr	MtCO2/yr	ECU/tCO2	B ECU/yr
Phase-Out Scenario, All Sectors						
Final energy, emissions, and costs in 2020	**920**	**2639**	**429**			
Net impact in 2020				**-1060**	*-158*	**-167**
Reduction (2020 HM = 1.00)				*-29%*		*-31%*

increase in emissions from the gas-for-nuclear substitution. Relative to the average cost of electricity generation in the Hypermarket scenario, these efficiency improvements save 19 billion ECU, which easily offsets the extra cost of replacement power incurred from phasing out existing reactors. For each ton of CO_2 reduction, EU electricity users save 53 ECU per year in 2020.

The next cheapest carbon reduction option is gas-fired cogeneration. These more climate-friendly plants replace about 670 TWh of conventional fossil generation, resulting in a year 2020 emission reduction of 140 Mt CO_2. This measure produces a slight cost saving, with industrial cogeneration being often significantly cheaper.

Finally, the IPSEP scenario adds 180 TWh of new renewable generation to that of the Hypermarket scenario. This leads to a further emission reduction of 79 million metric tons in 2020. Relative to rising fossil energy prices, the net extra cost of using renewables to substitute conventional generating options is about 3 billion ECU. A significant portion of these renewable energy sources comes from cost-competitive biomass sources and wind turbine sites. This dilutes the impact of other, currently more costly renewable generating options such as photovoltaics. The gross cost of these carbon reductions is 23 ECU per metric ton of CO_2 on average.

In combination, the above four measures allow the EU to completely phase out nuclear power by 2020 while at the same time reducing power sector carbon emissions by 545 million metric tons or 48 percent. The gross economic impact is not a cost, but a benefit of 7 billion ECU, equivalent to a 3 percent reduction in year 2020 electricity bills.

Power Sector: Net Impacts Including Feedback Effects

The economic impacts calculated so far do not yet include the feedback effects of the above strategy on technology costs, on the generating mix, and on fossil fuel prices. If one now adds in the benefit of lower energy efficiency and renewable costs (-15 billion ECU), lower average costs for the new generating mix supplying remaining demand (-13 billion ECU), and reduced pre-tax fossil fuel prices (-25 billion ECU), the net effect on EU electricity bills is a drop by about 60 billion ECU in 2020, or a 23 percent reduction relative to Hypermarket. For each metric ton of CO_2 avoided, a net saving of about 110 ECU is realized (see Table 9).

Of course, these figures are averages across the EU-15 as a whole. What about France, where the large majority of the reactor substitutions would have to occur? Based on the country's year 2020 electricity use, France's share of the total 60 billion savings in the power sector is 18 percent, or 11 billion ECU — just enough to offset all phase-out costs in the entire EU, and certainly enough to pay for the phase-out in France.

Impacts in Other Sectors

Table 9 also shows the carbon reductions and economic impacts from productivity investments in non-electric end-uses, such as industrial plants, transport vehicles, and building heating systems. Here, productivity measures including feedback effects result in a 33 percent reduction in energy service bills. Technology cost effects are again important, especially in the transport sector, where the mass manufacturing of high efficiency cars brings big cost reduction dividends relative to today's niche market prices. Here as in the power sector, roughly half of total cost savings come from the drop in pre-tax fossil fuel prices.

Externality Savings

The above analysis does not yet take into account the economic value of reduced classical and global warming pollution impacts. In the baseline Hypermarket scenario, improvements in classical pollution control technology result in significant reductions of sulfur dioxide, nitrogen oxides, and other energy-related classical air pollution emissions. Nevertheless, 5.7 million tons of SO2 and 8.7 million tons of NOx are still being released into EU-15 air sheds in 2020.

In the MINR 65/50 scenario, these remaining emissions are cut as dramatically again relative to Hypermarket as they were in Hypermarket relative to 1990 (see Figure 6 on page xii). SO2 emissions decline by 60 percent — again due, in large part, to further reductions in coal-fired power generation and less use of coal in industry. NOx emissions decline by almost 50 percent, in large part because high efficiency hybrid vehicles facilitate emission control, but also because emission-reducing cogeneration and non-combustion renewables contribute a significantly larger share to total power generation. In addition, the externalities of nuclear power generation are eliminated. On the other hand, renewable energy sources also produce some environmental impacts, and these make a larger contribution than in the Hypermarket scenario.

The valuation of these changes in environmental impacts is surrounded by considerable uncertainties, and many impacts have not been monetized in any study. The figures reported here rely both on the ExterneE study of the European Commission, which provides estimates for both fossil, nuclear, and renewable fuel cycles, and on similar valuation studies developed in the U.S. The central estimate for total damage cost in 2020 from classical pollution impacts in the EU-15 is about 50 billion ECU per year. Using central estimates, the IPSEP MINR 65/50 scenario would eliminate roughly 30 billion ECU or 60 percent of this total. A plausible uncertainty range is 10-50 billion ECU, with the ExterneE study pointing towards the high end of this range.

The valuation of impacts from global warming pollution is fraught with even greater uncertainties. A number of analyses suggest that in the aggregate, these externalities could be much larger than classical impacts from fossil fuel cycles. In the present study, we focus on the net cost of buying insurance against climate change. We thus refrain from using any monetized figures for this externality.

Overall Results

Across all sectors, the above strategy cuts year 2020 EU carbon emissions by more than 1000 Mt CO_2, bringing them 17 percent below 1990 levels. At the same time, pre-tax expenditures for energy services in 2020 are cut by 170 billion ECU/year relative to the scenarios of the Energy Directorate, or by thirty percent. More than half of this economic reward comes from lower pre-tax fossil fuel prices.

Avoided externality costs from classical pollution impacts further improve the mitigation cost balance sheet for the EU. Using central estimates, total economic welfare benefits rise to about 200 billion ECU/year in 2020. Note that these totals could be as low as 190 billion ECU and easily higher than 230 billion ECU.

The same results can be expressed in terms of economic savings per ton of carbon dioxide emissions that is being avoided. Using our central externality estimates, classical air pollution yields an externality-related benefit of about 10 ECU per ton of CO_2 avoided. By 2020, an investment-led productivity strategy for cutting carbon emissions would add a further 160 ECU/t CO_2 from reduced expenditures for heating, lighting, driving, and other energy services (see Table 9 on page 22), for a total saving of 170 ECU/t CO_2 avoided. These results stand in stark contrast to macroeconomic modeling exercises suggesting costs of the same order of magnitude, rather than benefits.

MACROECONOMIC ASPECTS

Our calculations so far have centered on savings in energy service expenditures and externality costs, assuming a fixed level of demand for driving, heating, lighting, steel production, etc. These computations do not yet fully measure the potential gdp and job benefits Europe could garner from a carbon reduction strategy. Quantitative estimates of these effects require the use of macroeconomic models. This type of analysis was beyond the scope of our study. Nevertheless, a number of qualitative observations can be made.

Domestic and Global Effects on Economic Growth

A 170 billion ECU/year reduction in EU-wide energy bills is equivalent to two percent of GNP in 2020, or more than 1000 ECU per household per year. Cumulative savings over the period until 2020 are several times larger in present value terms. With these savings, production costs of firms and inflation will be lower, and consumers will have more money to spend. This will increase output, which in turn stimulates capital accumulation and growth in potential gdp.

This ripple effect can be crudely captured by a multiplier that indicates the total change in gdp relative to the change in direct costs for energy services. Based on rule of thumb values from macroeconomic modeling exercises, a saving in energy service costs equivalent to 1 percent of gdp may translate into a gdp gain of as much as two percent.[9] In attenuated form, a multiplier effect also would result for growth in the world economy as a whole.

Take-Back and Leakage Effects

While such multiplier effects further add to the potential economic benefits of carbon mitigation, they also lead to additional demand for travel,

9. The relationship between private mitigation costs and social costs various over time and is dependent on a number of modeling assumptions.

industrial processing, and other energy services, and with that, to additional carbon emissions beyond those derived for IPSEP's policy scenario. Correspondingly, the percentage reduction in carbon emissions relative to 1990 would be lower than calculated above.

This so-called take-back effect is likely to be small. First, in the EU itself, it is limited by saturation trends in the consumption of energy services. Second, energy tax policies and advantageous tax shifts can be used to direct disposable income toward less energy-intensive activities without negatively affecting economic output at large. Third, what additional energy services are purchased in response to higher growth will be delivered by a significantly decarbonized, high efficiency chain of energy supply and end-use technologies.

Take-back effects in developing countries could be more significant, since energy service demand there is far from saturation and climate-oriented energy tax policies are unlikely to be implemented soon. However, the large take-back or "leakage" effects predicted by some economic models are implausible: these models fail to capture the technological spill-over of productivity-oriented low carbon strategies in the EU and other industrialized countries. Many energy efficiency investments are similarly profitable or more profitable in developing economies than they are in the EU.

Most importantly, the large economic savings produced by smart climate policies far exceed the possible cost of neutralizing any take-back effects that may remain. The above magnitudes of economic savings can easily pay for additional abatement measures that do have a net cost, such as deployment of more expensive renewable energy sources, or fossil fuel decarbonization, carbon scrubbing, and sequestration.[10] Alternatively, such neutralization could be achieved through buying requisite carbon credits abroad.

In the IPSEP study, a significant level of take-back is anticipated in the design of the scenarios themselves, by selecting the more optimistic Hypermarket (HM) scenario rather than the Conventional Wisdom (CW) scenario as the baseline. In Hypermarket, world gdp for 2020 is 8 percent higher than in Conventional Wisdom. Similarly, world consumption of energy services is higher by 4.4 percent.

Growth and Jobs

An investment-led, productivity oriented low carbon strategy promises a boost to EU employment levels. First, as already discussed, lower expenditures for energy services mean lower inflation, higher real disposable income, and generally good news for economic growth.

Secondly, the energy sector is one of the most capital-intensive sectors of the economy. Doing away with 30 percent of the EU's energy service bill translates not only into a significant release of capital for more productive uses, but also means a shift to the more labor-intensive sectors of the economy, which will boost employment.

Third, as various EU member countries implement energy and carbon taxes, such a new tax affords an opportunity to lower taxes on capital and labor. At the same time, such a tax will steer additional consumer spending in the direction of less energy-intensive activities. Furthermore, revenues from such a tax or from equivalent fees can fund incentives for efficiency and renewables investments. This restructuring of the tax system will again boost capital accumulation and job growth.

SUMMARY

Rather than resulting in unavoidable economic burdens, a shift to a low carbon economy turns out to be an opportunity for growth in EU productivity and welfare. The multiple economic benefits of increased energy productivity far exceed the economic resources needed to buy down the cost of renewables *and* pay for an accelerated nuclear phase-out.

Opportunity Costs of Conventional Energy Strategies

Based on these findings, we conclude that

- With an investment-led energy productivity strategy, the effect on gdp of stabilizing and then reducing carbon emissions significantly below present levels would be decidedly positive.
- Significant macroeconomic costs will result for the EU from *not* pursuing greenhouse

10. For example, neutralizing a 10 percent take-back of year 2020 carbon mitigation in the EU would require a mere 5 percent of the economic savings shown in Table 9 above. At an estimated average cost for fuel decarbonization, scrubbing, and sequestration of about 75 ECU/t CO_2, a 10 percent loss of mitigation, or 100 million tons of CO_2, would cost about 8 billion ECU per year.

gas reducing energy options. Job losses and slower economic growth are more likely under business-as-usual energy policies than under productivity-oriented greenhouse gas reduction strategies.

Put another way, business-as-usual strategies have significant opportunity costs that have largely gone unrecognized to date.

Why Mitigation Cost Estimates Differ

The above conclusions are in stark contrast to many previous mitigation cost assessments. This divergence in findings is explained by analytical differences that are worth summarizing here. Modeling studies reporting significant economic burdens from domestic greenhouse gas mitigation suffer from some or all of the following shortcomings:[11]

a. Incomplete technology menus and cost and policy assessments, notably in the area of demand-side efficiency improvements, but also of cogeneration and renewable energy options;

b. Failure to account for system-level benefits of energy efficiency and many renewable energy technologies in the areas of distribution costs and upstream and downstream capital requirements;

c. Failure to evaluate demand-side and supply-side options from an internally consistent societal perspective on discount rates, opportunity costs, and risks;

d. Neglect of important cost-saving economic and technological feedback effects from climate protection policies;

e. Omission of economic benefits from avoided air pollution damages and other externalities; and

f. Failure to correct for the distorting effects of subsidies that support fossil fuels and fossil-fuel intensive transport modes.

Even a partial, less than complete correction of these shortcomings turns conventional wisdom on its head, as illustrated by the results reported above. In commissioning future economic assessments of mitigation options, governments should above all insist on the modeling of productivity-enhancing market transformation policies, based on inputs from competent studies.

11. For a detailed discussion of modeling shortcomings in current U.S. and European mitigation cost studies, see e.g., Krause (1998, 1996).

V. What Policies Are Needed?

Carbon Reduction Policies at Home

While carbon reductions in the EU could be robustly advantageous in economic terms, realizing these gains requires a suitable mix of policies. Among economists, the favored mechanism are cross-cutting instruments such as carbon taxes, or tradable emission permits. Unfortunately, carbon reduction targets cannot be achieved in an economically efficient manner through such cross-cutting instruments alone.

Correct price signals and focus on the cheapest opportunities for mitigation are clearly desirable. However, carbon taxes or tradable emission rights by themselves are a blunt tool without specific regulatory policies and incentives programs. Without such measures, pervasive market and regulatory barriers will continue to make price signals as ineffective in bringing about least-cost investments as they are in many areas today. Carbon taxes alone are also obviously unsuited for assuring specific reductions by specific dates.

A Checklist

Profitable carbon mitigation requires an integrated approach, consisting of a number of policy instruments that complement each other:

1. Legally binding national and EU-wide targets and timetables for cutting global warming pollution, coupled with market mechanisms for carbon emission trading;
2. Similar targets for increasing the share of renewable energy in EU electricity production and other applications.
3. Voluntary agreements and minimum energy efficiency standards for buildings, appliances, lighting systems, vehicles, and other suitable end-uses, with scheduled updates every five years or so.
4. Complementary extension services, financing, and incentive programs to help industries and consumers invest in cost-effective equipment, vehicles, homes, appliances, etc. whose efficiencies exceed standards or for which standards cannot be implemented.
5. Feebate programs that finance rebates on purchases of energy-efficient vehicles, buildings or other energy-using assets by fees on inefficient ones.
6. Regulatory reforms in the utility sector that provide fair prices and grid access for independent power producers, and port-folio standards that ensure a rapid increase in contributions from cogeneration and renewable energy sources.
7. Surcharges on utility rates for financing programs that help households and firms adopt energy-saving technologies.
8. Financial incentives *(golden carrots)* for manufacturers that increase the energy efficiency of their products beyond best available levels.
9. A reorientation of EU and national research and development programs toward least-cost carbon reduction options.
10. Combined carbon/energy taxes sufficient to help fund the above carbon substitution programs plus an across-the-board shift in the tax structure from labor and investments to pollution.
11. Special policies for energy-intensive, export-sensitive industries, in exchange for meaningful energy efficiency measures.

In this integrated approach, energy/carbon taxes are primarily a funding or subsidy mechanism for market transformation programs supporting low carbon technologies. These non-price policies are the main drivers of a profitable, productivity-oriented mitigation strategy. Energy and carbon taxes support these programs by keeping after-tax prices from declining as carbon abatement proceeds. They also can provide a supplementary price signal. This price signal, in turn, is made more effective because reductions in transaction costs and other market barriers have the effect of raising the price elasticity of energy demand.

The EU So Far: More Talk Than Action

The European Commission has variously proposed common and coordinated policies consisting of both an energy/carbon tax and other measures including a number of the above options. The major problem at this time is a broad lack of implementation.

Currently, the Kyoto target of 8 percent has no legally binding status for carbon reductions specifically. No renewable energy obligation is in effect or under way in the EU. Fair access rules have been developed for large industrial cogenerators, but are insufficient for district heating and small cogenerators. Europe's minimum efficiency standards for appliances are limited in coverage and technologically out of date, while lacking mandated schedules for updates.

Likewise, the recent voluntary agreement with EU automobile manufacturers on passenger car fuel economy achieves, at 6 liter/100 km, only a fraction of technological possibilities. Tariff-based or other financing for effective utility efficiency programs does not exist in most countries. In industry, little progress has been made EU-wide with voluntary agreements to cut energy intensity. And proposals for an EU energy and carbon tax continue to go nowhere.

Based on a recent review of the current state of implementation, the EU might at best realize a quarter of the 800 Mt CO_2 emission reduction once envisioned by the Commission for the year 2010, and this mostly on account of national actions by only a few member states.[1]

Buying Emission Credits Abroad: The Economics of "Elsewhere" Flexibility

The above findings of significant direct and macroeconomic benefits suggest that a strategy to reduce carbon emissions swiftly is good competitiveness policy for large economic regions such as the EU, irrespective of whether other countries follow suit.

Of course, there is still a need for coordinated global action: carbon-cutting productivity gains do not just fall into one's economic lap; the extent and speed of such gains depends on policy action in a field of conflicting special interests. International agreements are crucial in subordinating these special interests to larger environmental and economic efficiency goals.

Furthermore, the benefits of lower technology costs and fuel prices is maximized when the major economic regions act at once. Also, the many smaller countries in the world lack the market power to fully induce these beneficial feedbacks on their own.

However, the notion of economic gain rather than pain opens a very different perspective on the issue of flexibility mechanisms under the Kyoto protocol.

Economic Rationale for Flexibility Mechanisms

In its original version, the Kyoto treaty foresaw that the so-called flexibility mechanisms (joint implementation, the clean development mechanism, and emissions trading among Annex I countries) would be used only as a supplement to domestic Annex I action. The U.S. and some other countries have argued that all Annex I signatories should be allowed to realize up to 100 percent of their Kyoto commitments through flexibility mechanisms, while the EU and other countries have insisted on a cap on flexibility contributions.

The call for 100 percent "elsewhere" flexibility is being justified on the grounds of these claims:

1. Opportunities for reducing domestic emissions through productivity-raising investments are insignificant in Annex I countries.
2. Realizing the Kyoto targets will mean a substantial economic burden on Annex I signatories, both individually and as a group.
3. There are significant national differences in mitigation costs among Annex I countries.
4. Emission reductions can generally be realized at lower cost in developing countries and in the formerly socialist economies than in Annex I countries.
5. If climate policy goals are to be realized in a least-cost manner, high emitters like the U.S. and other wealthy industrialized regions should be allowed to earn full credits for any emission-reducing investments undertaken anywhere, not just for measures taken at home.

1. See Phylipsen et al. (1998), who compare policy actions to date with an earlier assessment of the European Commission's expert group (Phylipsen et al. 1997).

When "Elsewhere" Flexibility Produces Losses

This superficially appealing line of reasoning collapses when faced with the results of the present study, and with similar work for the U.S.[2] Against findings of large net benefits from productivity-oriented low carbon strategies, the notion that a 100 percent offset of domestic commitments would be economically efficient, either for Annex I economies or for the world as a whole, is easily recognized as flawed. Instead, a different perspective emerges on the "elsewhere" issue, one that reaffirms the original design of the Kyoto protocol simply on economic efficiency grounds:

- The key proposition – that Annex I countries lack cost-saving opportunities for domestic emission reductions – is at odds with empirical evidence from ongoing policy programs. It also is at odds with modern economic thought, which recognizes the role of transaction costs, institutional arrangements, and related policy choices in shaping market performance. Modeling studies relying on optimized market assumptions and fixed coefficients for energy efficiency improvements are outdated and produce misleading results.
- The major portion of Annex I Kyoto commitments, and/or of further reduction targets for the year 2020, can be realized through the removal of widespread market barriers that currently impede profitable investments in productivity-enhancing energy efficiency technologies.
- Allowing most Annex I emission reductions to be realized through "elsewhere" mechanisms would create significant opportunity costs for Annex I consumers and energy-using firms. Rather than obtaining emission reductions from profitable domestic action, they would end up paying for investments abroad that provide carbon reductions at a net cost.
- Uncontrolled "elsewhere" flexibility would deprive local and regional domestic economies of ancillary environmental benefits associated with carbon reduction strategies, i.e., lower damage costs from classical air pollution impacts. These can be large enough to offset the cost of some otherwise more costly measures, such as retiring older, less efficient but fully depreciated fossil-fired powerplants.
- The opportunity costs of foregone energy productivity and environmental investments would be compounded by losses from delayed innovation. A focus of Annex I countries on easy measures abroad would plausibly lead to a slowing and postponement of learning by doing in the more advanced areas of technology development.
- Further potentially large opportunity costs would be imposed on developing countries. Without large-scale technological and market changes in the leading OECD countries, access to productivity-enhancing, capital-saving, profitable end-use technologies in the developing regions would be delayed – just at the time when their energy-using capital stocks are undergoing rapid growth.
- Even when cost-effective domestic options have been exhausted, the transaction and verification costs associated with the various emission reduction crediting schemes may in many cases offset the perceived cost advantages of "elsewhere" investments.

Having said this much about the opportunity costs and other limitations of excessive "elsewhere" flexibility, there are, of course, many individual cases when such flexibility does make sense for all parties concerned. Generally, investments in mitigation elsewhere makes sense

- when projects abroad do not take away from the full implementation of domestic technology and policy measures that are profitable in their own right;
- when projects abroad do not displace domestic investments in technologies with a high potential for innovation and cost reduction;

2. For the U.S., a series of analyses yielding broadly similar results has been recently completed by Interlaboratory Working Group (1997), Koomey et al. (1998), Tellus/SEI (1999) and in a forthcoming update of the 1997 Interlaboratory Working Group study that confirms previous findings of large negative-net-cost potentials for reducing carbon emissions in the U.S.

- and when the local and regional environmental benefits of domestic carbon abatement have been properly valued and taken into account.

Our above analysis for the EU suggest that based on these criteria, less than 10 percent of EU emission reductions could be advantageously pursued outside the European Union.[3]

Policy Implications

The insistence of the EU and other countries on limiting "elsewhere" flexibility to a supplementary percentage is in alignment with and supports a least-cost implementation of the Kyoto targets. An unmitigated "elsewhere" policy would slow and undermine the crucial process of productivity investments and low-carbon technological innovation in Annex I countries. As such, it would represent a large wealth transfer to the fossil energy supply sector from other sectors of the economy, both in Annex I countries and in developing countries. In effect, a full or predominantly "elsewhere" approach would sacrifice significant productivity and technology innovation benefits for the economy as a whole in order to protect a limited amount of sunk investments in obsolete energy supply infrastructures.

3. See Table 9. The main group of measures with positive net costs is represented by renewable power investments, which constitute about 8 percent of total year 2020 carbon reductions in the MINR 65/50 scenario. Given the importance of domestic EU renewable market growth for bringing down technology costs, advantageously tradable emission reductions are likely to be even smaller. However, some flexibility offsets could be advantageous for energy-intensive export-sensitive firms.

VI. Conclusions

Outdated economic modeling studies have severely distorted the international policy debate on climate protection. With a productivity-oriented climate strategy, the European Union could garner significant gdp, employment, and competitiveness benefits from implementing its Kyoto commitment for 2010. Reductions below 1990 levels could be more than doubled by 2020, at an even greater net economic benefit.

Because of large domestic opportunities for increasing energy productivity, the EU could profitably decarbonize its economy even as it reduces its dependence on gas imports and nuclear power. A predominant reliance on the Kyoto flexibility mechanisms would not be economically efficient for the EU and would result in significant opportunity costs for consumers and energy-using firms.

To realize climate protection at a profit, the EU needs to correct severe policy deficits. Current EU policies aimed at energy market liberalization do not eliminate market barriers to energy productivity investments. They also may lock out renewables. What is needed is a climatically sound restructuring of European energy markets. Such restructuring would involve both deregulation, institution-building, and new voluntary and regulatory policies that improve the markets for energy efficiency, cogeneration, and renewables.

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